



ANNUAL REPORT TO CONGRESS— FISCAL YEAR 2004

**from the
Strategic Environmental Research
and Development Program**

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EXECUTIVE SUMMARY

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's (DoD) corporate environmental science and technology program. To fulfill its mission to address environmental problems through innovative research and share that information across federal and private organizations, SERDP executes the program in partnership with the Department of Energy (DOE) and the Environmental Protection Agency (EPA). Further, SERDP fully leverages complementary programs within the DoD and solicits interest from other public and private research organizations.

The organization and management of SERDP is described in Section I—Program Management. As directed by the SERDP Council, the Executive Director and Program Office Staff implement the Program with the support of various working groups and panels to meet high priority, DoD mission-related environmental needs. The activities, achievements, and recommendations of the SERDP Council, Scientific Advisory Board (SAB), and Executive Director are detailed in this section.

SERDP conducts basic research through advanced technology development in the following five Technology Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO). Section II—Investment Strategy And Performance describes significant accomplishments achieved during FY 2004 within the two major investment strategy areas: Sustainable Training and Testing Ranges and Reducing Current and Future Liabilities. Highlights of these accomplishments include: (1) an improved understanding of the fate and transport and immobilization of energetics on live fire training ranges; (2) new tools and methods to more rapidly and cost-effectively identify and monitor threatened and endangered species; (3) increased knowledge base to understand the generation and characteristics of dust and particulate matter emitted from DoD training activities; (4) the elimination of hazardous air emissions from coatings processes and combustion sources; (5) novel technologies for the remediation of energetics and chlorinated solvents at DoD facilities and (6) advanced sensors and data processing algorithms to improve detection and discrimination of buried UXO.

In each fiscal year cycle, SERDP must manage ongoing research within the program, solicit and select new research projects, and plan future research initiatives and funding distribution for each Thrust Area. Section III—Program Description provides an overview of the SERDP Program, including the goals, environmental and operational research drivers, actual and planned funding levels, and the planned research initiatives for the Program. In FY 2004, SERDP was appropriated \$50.6 million for the funding and management of 148 research projects. The FY 2005 appropriation of \$57.9 million will be used for at least 128 projects, including both continuing and new start projects. Lists of projects funded in FY 2004 and those planned for funding in FY 2005 are provided in Section II. Research topic areas for which proposals will be requested for projects to be funded in FY 2006 are also provided in Section II.

This report provides a summary of SERDP's activities and its most significant accomplishments for FY 2004, its plans for FY 2005, and new research activities to be addressed in FY 2006. It responds directly to the requirements as stated in Title 10, U.S.C. section 2902, as modified.

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Acronyms and Abbreviations

AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
B-IBI	Benthic Index of Biotic Integrity
BAA	Broad Agency Announcement
BAMAS	Bearing and Amplitude Measurement and Analysis System
BLM	Biotic Ligand Model
BRAC	base realignment and closure
CAAA	Clean Air Act Amendment
cis-DCE	cis-1,2-dichloroethene
Cr	chromium
Cu	copper
DCERP	Defense Coastal/Estuarine Research Program
DNAPL	dense non-aqueous phase liquid
DoD	Department of Defense
DOE	Department of Energy
DTIC	Defense Technical Information Center
DUSD(I&E)	Deputy Under Secretary of Defense (Installations and Environment)
DUSD/S&T	Deputy Under Secretary of Defense for Science and Technology
EM	electromagnetic
EMI	electromagnetic induction
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESTCP	Environmental Security Technology Certification Program
EWG	Executive Working Group
FD	frequency domain
FERM	Fire Ecology Range Management
FUDS	formerly used defense site
FY	fiscal year
GIS	geographic information system
HAP	hazardous air pollutant
HMM	hidden Markov model
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
INRMP	Integrated Natural Resource Management Plan
ISCO	in situ chemical oxidation
JSF	Joint Strike Fighter
LBNL	Lawrence Berkeley National Laboratory
LUCAS	Land-Use Change Analysis System

Acronyms and Abbreviations (continued)

MC	munitions constituent
MLFMA	multilevel fast multipole algorithm
MMPA	Marine Mammal Protection Act
MRE	meal-ready-to-eat
MURI	Multiple University Research Initiative
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Protection Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NSWC-Crane	Naval Surface Warfare Center-Crane Division
ODS	ozone depleting substance
ODUSD(I&E)	Office of the Deputy Under Secretary of Defense (Installations and Environment)
ONR	Office of Naval Research
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PI	principal investigator
PM	particulate matter
POI	point of impact
PVC	polyvinyl chloride
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RCW	red-cockaded woodpecker
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RSim	regional simulator
S&T	Science and Technology
SAB	Scientific Advisory Board
SAR	Synthetic Aperture Radar
SEED	SERDP Exploratory Development
SEMP	SERDP Ecosystems Management Project
SERDP	Strategic Environmental Research and Development Program
SON	Statement of Need
SROC	Senior Readiness Oversight Council
TES	threatened and endangered species
TNT	2,4,6-trinitrotoluene
TRI	toxic release inventory
TTAWG	Technology Thrust Area Working Group
USAF	U.S. Air Force
UWB	ultra-wideband
UXO	unexploded ordnance
VC	vinyl chloride
VE	vinal ester
VOC	volatile organic compound
WQC	water quality criteria

I. SERDP STRUCTURE

A. Background

Established in 1991, the Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's (DoD) corporate environmental Science and Technology (S&T) program. This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year (FY) 2004, its plans for FY 2005, and new research initiatives to be addressed in FY 2006. It responds directly to the reporting requirements as stated in Title 10, U.S.C. §2902. Subsection 2902(d)(3) was amended in 2000 to include subsection (D), which requires that the SERDP Annual Report contains a summary of the actions and recommendations of the SERDP Scientific Advisory Board (SAB) during the preceding year.

i. Authorizing Legislation

In 1990, Public Law 101-510 (Title 10, U.S.C., §§2901-2904) established SERDP to be funded by the DoD and planned and executed in partnership with the Department of Energy (DOE) and the Environmental Protection Agency (EPA). SERDP fully leverages complementary programs found within the Army, Navy, and Air Force, and those of the DOE and the EPA. Over the past decade, SERDP has taken full advantage of the intrinsic capabilities of the participating organizations. This feature makes SERDP unique, as it can tap the vast technical resources of the Federal research infrastructure to meet the needs of the Departments' most pressing environmental matters of concern. For the past 8 years, SERDP also has successfully engaged in directly funding the private sector and academia, further widening the spectrum of technological capability and innovation.

ii. Mission

SERDP's mission can be found in the statute and is paraphrased below. Specifically, the four purposes of SERDP are to:

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations.
- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations.
- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research.
- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and

SERDP addresses DoD and congruent DOE environmental matters of concern through cooperative research.

prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

This mission, crafted more than 14 years ago, remains highly relevant, and while significant successes have been achieved, a number of difficult technical challenges remain.

iii. Requirements

SERDP is a “requirements-driven” program that responds directly to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense (Installations and Environment) [DUSD(I&E)]. It is critical that the limited funds available for environmental technology research and development (R&D) be focused on the highest priority requirements of the Services.

The DoD’s environmental issues fall into two major categories. The first is the sustainability of the Department’s Training and Testing Ranges. Many of these ranges are under restrictions due to environmental issues and, in a few extreme cases, a range has been unable to function at all. Access to adequate training ranges in perpetuity is essential to maintain military readiness. To assure this access, environmental issues associated with the ranges must be addressed. The second major driver is the reduction of current and future liabilities. Current liabilities are associated with the remediation of contamination from past practices. These liabilities are relatively well known and have been estimated to total \$13.6 billion. However, that estimate does not include the liability from unexploded ordnance (UXO) or emerging contaminants such as perchlorate (ClO_4^-). Future liabilities are in the form of the toxic and hazardous materials and emissions from today’s weapons and platforms. Through the aggressive development of new, benign materials and industrial processes as well as control technologies, the use and release of these materials to the environment can be reduced or eliminated. Technology has proven to be capable of significantly reducing the cost of addressing all these liabilities.

These two major categories of environmental issues have a direct impact on DoD’s ability to perform its primary mission of maintaining military readiness for national defense. For the ease of managing the program, SERDP places all research efforts to address these issues into one of five thrust areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance. In the course of addressing DoD’s highest priority environmental needs, SERDP also has sought opportunities to help solve other significant national and international environmental problems by applying DoD’s technical capabilities, analytical systems, and information.

B. SERDP Management Structure

SERDP is a multiagency managed program funded by the DoD. Pursuant to Title 10, U.S.C. §§2901-2904, SERDP receives general oversight and policy guidance from the SERDP Council, which is composed of members from the DoD, DOE, and EPA. Also included in this authorizing language is a requirement for an Executive Director to lead the day-to-day Program activities, as well as an SAB that is charged with providing advice and recommendations to the SERDP Council on projects/proposals reviewed. Further, the SAB may advise the Council regarding other programmatic, funding, or technically related issues with respect to the Program. The organizational structure shown in Figure I-1 was established by the Council and Executive Director to support Program needs.

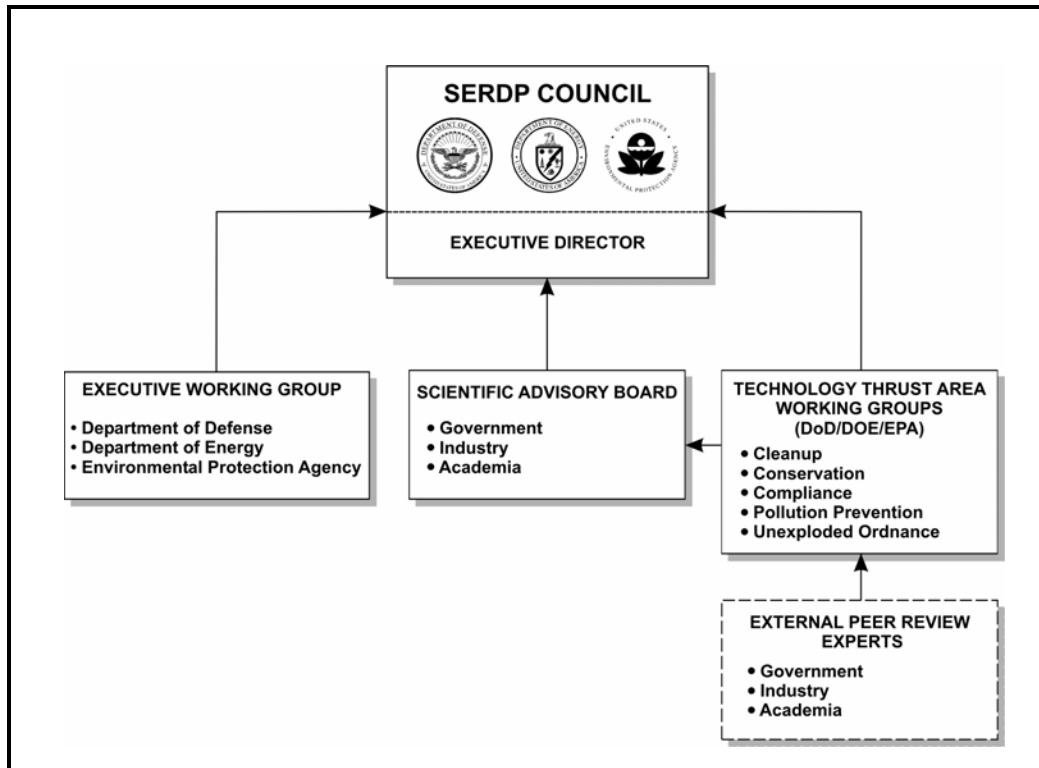


Figure I-1. SERDP Organization.

i. SERDP Council

Title 10, U.S.C. §2902 established the SERDP Council to oversee the management of SERDP. Specifically, this Council prescribes policies and procedures to implement the Program and, uniquely, is the sole funding approval authority. As such, the Council may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multiagency membership body to promote maximum exchange of information and to minimize duplication of environmentally related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the DOE; the EPA, the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the federal, state, and local governments; and other organizations engaged in environmentally related research.

Established by law, SERDP's multi-agency Council ensures integrated, nonduplicative research.

DoD and DOE Council representatives alternate as Chair

Consistent with the SERDP statute and with facilitating multiagency cooperation, the Secretary of Defense has designated the Deputy Under Secretary of Defense for Science and Technology (DUSD/S&T) as chairperson for each odd-numbered fiscal year, and the Secretary of Energy has designated the Director of the Office of Science to serve as chair for each even-numbered year. Other members are assigned per guidance provided in the SERDP statute. The following are the

Council members who served during a portion of, or for the entire, FY 2004.

Council Members - FY 2004

Dr. Everet H. Beckner
Defense Programs
National Nuclear Security Administration
U.S. Department of Energy

Dr. Stephen Lubard
Science & Technology
Office of Naval Research (ONR)
U.S. Navy

Lt. Col. Jeff Cornell
Office of Deputy Assistant Secretary of the
Air Force
Environment, Safety and Occupational Health
U.S. Air Force

Captain Jay Manik
Office of Research and Development
U.S. Coast Guard

Mr. Ray DuBois
Deputy Under Secretary of Defense for
Installations & Environment
Department of Defense

Dr. Ray Orbach
Office of Science
U.S. Department of Energy

Mr. Mark Gilbertson
Office of Environmental Management
U.S. Department of Energy

General Peter Pace
Joint Chiefs of Staff

Dr. Paul Gilman
Office of Research and Development
U.S. Environmental Protection Agency

Dr. John Parmentola
Research and Laboratory Management
U.S. Army

Mr. Bradley Smith (*non-voting member*)
Executive Director
Strategic Environmental Research and
Development Program

Dr. Charles J. Holland
Deputy Undersecretary of Defense, Science
and Technology
Department of Defense

ii. Executive Working Group

The Executive Working Group (EWG) is an extension of the Council and serves as a working-level representation of the Council. This body, while not established by law, facilitates SERDP policy preparation, investment strategy considerations, and annual program plan development.

iii. SERDP Scientific Advisory Board

Established in accordance with the SERDP statute, the SERDP SAB assures that the Program maintains clear focus on technical quality. The SAB has the authority to make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP. The SAB is composed of no more than 14 and no less than 6 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the EPA. During FY 2004, three members completed their tenure on the Board late in 2004. With the departure of three members in 2003 and the delay of appointment of the 2004 candidates by DOE, the Board will be left with a total of 4 members. SERDP has identified new candidates for membership in 2005.

**SAB members
focus on technical
quality.**

To ensure that SERDP objectives are congruent with the Administration's goals, two members of the SAB are mandated in the statute—the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that regional and global environmental issues are appropriately addressed in SERDP, at least

one member should represent the interests of State governments and one member should represent environmental public interest groups. The list below reflects SAB membership in FY 2004.

Scientific Advisory Board Members - FY 2004

Dr. Paul Anastas White House Office of Science and Technology	Dr. William Neff National Oceanic and Atmospheric Administration
Dr. Mary Barber The Ecological Society of America	Dr. Jeffrey J. Siirola Eastman Chemical Company
Dr. Jeffrey Daniels The Ohio State University	Dr. C. Herb Ward (Chair) Rice University
Dr. Teresa Fryberger White House Office of Science and Technology	Mr. Randolph Wood Texas Natural Resources Conservation Commission
Dr. Ronald Heck RMH Consulting	Dr. Lily Young Rutgers University
Dr. Michael Kavanaugh Malcolm Pirnie, Inc.	

The statute directs the SAB to review all projects with a value in excess of \$1,000,000. Several years ago, the SERDP Council modified this direction by requesting that each new start effort and every continuing project exceeding \$900,000 be reviewed by the SAB.

iv. Executive Director and Program Office Staff

Title 10, U.S.C. authorizes an Executive Director to direct and focus the day-to-day efforts of SERDP, and Mr. Bradley P. Smith retained the position of Executive Director in FY 2004. The Executive Director is a non-voting member of the SERDP Council and a voting member of the EWG. Dr. Jeffrey Marqusee, the Environmental Security Technology Certification Program (ESTCP) Director, also served as the SERDP Technical Director. Colocation of SERDP and ESTCP has served to broaden the staff's technical skills and facilitate technology transition from one program to another. The balance of the federal staff consisted of four technical Program Managers and two Financial Officers who have been detailed from the military Services' R&D infrastructure. These individuals include:

- Dr. Anne Andrews - Program Manager for UXO technologies
- Dr. Andrea Leeson - Program Manager for Cleanup technologies
- Mr. Charles Pellerin - Program Manager for Pollution Prevention technologies
- Dr. Robert Holst - Program Manager for Compliance and Conservation technologies
- Ms. Brenda Batch - Financial Officer
- Ms. Margaret Banks - Financial Officer

v. Technology Thrust Area Working Groups

As evidenced by the small size of its staff, the breadth of technical knowledge demanded by SERDP far exceeds the limited staff in the SERDP Program Office. Consequently, SERDP must rely on the technical skills offered by the participating Services and Agencies to assist in the technical aspects of program development, program monitoring, and technology transfer. For each of the Technology Thrust Areas, a Technology Thrust Area Working Group (TTAWG) was established to help solicit and review technical proposals, formulate and recommend the annual program plan, conduct technical reviews of the ongoing projects, and facilitate technology transfer according to the needs of their users in the field. TTAWGs offer several advantages over conventional R&D management schemes. First, their members are selected by the Services and Agencies as represented on the Council. Second, they bring not only a wealth of understanding of the needs of their organization, but also knowledge of similar completed or ongoing efforts. This knowledge helps SERDP to avoid duplication of effort and promote joint and cooperative funding of projects.

vi. Peer Reviewers

Assisting the TTAWGs and the Program Office in their quest to select quality research proposals are the Peer Reviewers. Following the model established by the National Science Foundation, SERDP proposals must undergo an independent Peer Review prior to receipt of initial funding. The results, scores, and evaluation comments from this review are provided directly to the TTAWGs who use this information to develop their recommended list of new start projects. Further, these same results are provided to the SAB for consideration during their proposal review and deliberations.

SERDP supports an electronic peer evaluation process via the Internet.

C. SERDP Management Philosophy

The SERDP Council ensures that the Program focuses on the mission needs of the DoD and empowers the EWG with developing goals and an investment strategy that will help SERDP satisfy these mission needs successfully. The SERDP management goals and investment strategy then are shared with the SAB, TTAWGs, and Peer Reviewers. By leveraging complementary research programs, SERDP is able to avoid duplication of effort and to facilitate the transfer and implementation of innovative research and technology – maximizing advancements in the state of the science and engineering for DoD.

i. Technical Goals

In 1993, the EWG assembled to develop the broad framework within which to develop the annual SERDP program plan. Included in this document are the SERDP goals, which are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems' effectiveness, and help ensure the safety of personnel.
- Support technology and process developments that reduce operational and life-cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP achieves its goals by promoting cooperative environmental technology development and by maintaining a strong effort in information dissemination. Specifically, SERDP succeeds by:

- Promoting the effective exchange of information regarding environmentally related research and development activities.
- Ensuring that SERDP R&D activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities.
- Providing appropriate access to data under the control of or otherwise available to the DoD and DOE that are relevant to environmental matters.
- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society that may be able to use them to advance national environmental objectives.
- Emphasizing multiservice, interdepartmental research and development projects and using the unique capabilities of the partnering federal agencies, private industry, and academia to solve the Departments' environmental problems.

SERDP promotes cooperative environmental technology development and information transfer.

ii. Key Metrics for SERDP Success

The following four key metrics are used to maintain the quality and enhance the success of the Program.

The Executive Director and his staff worked hand-in-hand with Office of the Deputy Under Secretary of Defense (Installations and Environment) [ODUSD(I&E)] to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Through focused Statements of Need (SON)

1. Address the highest priority defense, mission-relevant environmental requirements, with emphasis on multiservice issues.

in the Core and SERDP Exploratory Development (SEED) solicitations, the Executive Director sought cooperatively funded and executed projects to address high-priority multiservice needs.

SERDP often holds workshops to explore the state-of-science, technology gaps, and opportunities for research in areas where it may be difficult to interpret this need. From these workshops, several key SONs can be identified. In FY 2004, SERDP staff conducted a workshop on contaminated sediments in aquatic environments and another on the state of the science and engineering for electromagnetic induction (EMI) technology used for the detection and discrimination of UXO.

World-class research is considered the cornerstone of SERDP projects. Continuing the successful solicitations of the past few years, SERDP solicited proposals from all sources, including the nonfederal sector. SERDP continued to use external Peer Reviewers in addition to the comprehensive multiagency review procedures to ensure that technically sound proposals performed by world-class researchers are selected for funding.

2. Pursue/achieve universal, world-class technical excellence.

3. Emphasize and promote technology transfer.

Transfer of technology, from research to the DoD user community, is one of the key objectives of SERDP. This objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority, DoD mission-related environmental needs. The colocation of

ESTCP with SERDP has helped to facilitate technology transitions between Programs, into other Agencies' certification programs, and to the DoD user community.

Timely and complete financial reporting is one of the keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of limited R&D resources, and using various information management/monitoring tools that fully utilize state-of-the-art Internet capabilities.

**4. Ensure sound
fiscal management.**

II. INVESTMENT STRATEGY AND PERFORMANCE

A. Approach

As a leader in the field of environmental technology research and development, SERDP provides solutions to both new and persistent priority environmental matters of concern to the DoD and the DOE. With an effective outreach program that includes technology gap analysis studies, SERDP strives to remain ahead of the curve, identifying high-priority and emerging environmental technology requirements. SERDP has supported hundreds of science and technology projects since the Program's inception in 1991 in the areas of cleanup, compliance, conservation, pollution prevention, and unexploded ordnance. These projects have enabled DoD installations to meet their environmental responsibilities using cost-effective and innovative methods.

SERDP's investment strategy aims to provide DoD with the best available solutions to its toughest environmental challenges, including (1) sustainable training and testing ranges and (2) reduction of current and future liabilities. This section describes a selection of SERDP's most significant accomplishments in each investment area during FY 2004. While representing only a small sample of the many innovative projects supported by SERDP, these accomplishments demonstrate the breadth and depth of the program and highlight the types of major technical advances resulting from focused research and development. Moreover, many of these accomplishments illustrate potential cost savings resulting from full implementation of new technologies while simultaneously maintaining military mission readiness. This section also includes a listing of all SERDP projects funded in FY 2004, new projects funded for FY 2005, and initiatives planned for FY 2006.

B. Sustainable Training and Testing Ranges

The impacts of environmental regulation on military training and testing operations have slowly grown over time until the Department is now faced with serious limitations to the ability to provide realistic training. The DoD's Senior Readiness Oversight Council (SROC) recognizes six key environmental areas impacting the training and testing ranges: UXO and Munitions Constituents (MC), Threatened and Endangered Species (TES), Maritime Sustainability, Air Quality, Noise, and Urban Encroachment. As the number of ranges decreases, the existing ranges are being used more extensively. To ensure that the ranges continue to provide a realistic setting for training, there is a need to manage installations in a manner that will support training without causing irreversible damage and will reduce the cost of restoration. Tools also are needed to help manage the ranges as whole ecosystems in a regional setting that permits maximum utility of the range while preserving mission capabilities into the future.

i. Munitions Constituents

Scope of Problem

The use of munitions is an integral part of the military's testing and training. Energetic materials including propellants, explosives, and pyrotechnics are widely used by DoD, and an estimated 500 million pounds of energetic materials are produced each year, generating millions of pounds of hazardous waste. The compounds that are of primary environmental concern include TNT, RDX, HMX, and perchlorate. These MCs have been identified in soil and groundwater at former and current ammunition manufacturing sites as well as at military testing and training ranges.

There exists a growing concern that the accumulation of unexploded or unconsumed MC residues on military testing and training ranges represents a threat to human health and the environment. These residues, which can take the form of discrete “chunks” or very fine particles, may dissolve and leach into groundwater or be carried off-site in runoff. The DoD requires range management practices that effectively reduce quantities of MC residuals and minimize disruptions in testing and training activities. Other challenges include developing appropriate remedial actions to address site contamination and treating contaminated soil and groundwater to ensure regulatory compliance.

Overview of Investment

Investments in the area of MC span the Cleanup, Compliance, and Pollution Prevention thrust areas. SERDP seeks to provide range managers with techniques to assess the potential for soil and/or groundwater contamination, to remediate such contamination, and to reduce or eliminate future contamination. To achieve this goal, it is first necessary to determine where these compounds originate and how they are released into the environment. Data on the physical, chemical, and biological properties of MC are essential to understand the fate and transport of MC released in the environment. Through an understanding of how these materials move and are transformed in the environment, reliable and scientifically defensible risk assessments can be developed, as can protocols to mitigate the impacts. This knowledge supports the development, design, and management of sustainable training and testing ranges.

In contrast to most soil and groundwater contaminants, the distribution of MC contamination is normally highly heterogeneous. Unique sampling protocols and technologies are required for accurately characterizing and monitoring MCs. When MCs are released into the environment, treatment or containment technologies for soil and groundwater are required to prevent unacceptable exposure. Range managers require techniques that are applicable to small and large areas, as well as practices that prevent MCs from migrating off ranges.

While technology developments have improved munitions manufacturing, there still remains a percentage of rounds that malfunction, resulting in low-order (incomplete) detonations or duds. These low-order detonations and duds represent a continuing source of MC contamination on ranges. Elimination of toxic or hazardous materials from munitions will result in significant reductions in the cost of sustaining training and testing ranges for the military. The following initiatives have been funded by SERDP to accomplish the Program’s objectives for MC:

FY 2004 Completed Projects

- A Field Program to Identify TRI Chemicals and Determine Emission Factors from DoD Munitions Activities (CP-1197), Battelle Memorial Institute
- Microbial Degradation of RDX and HMX (CU-1213), National Research Council of Canada, Biotechnology Research Institute
- Immobilization of Energetics on Live Fire Ranges (CU-1229), Shaw Environmental & Infrastructure, Inc.
- Zero Valent Iron [Fe(0)]-Based Bioremediation of RDX-Contaminated Groundwater (CU-1231), Rice University
- Ecological Risk Assessment of Perchlorate in Avian Species, Rodents, Amphibians and Fish (CU-1235), Texas Tech University
- Twin Screw Extruder Production of MTTP Decoy Flares – Pollution Prevention through Solvent Elimination (PP-1240), Thiokol Propulsion

- Environmentally Acceptable Medium Caliber Ammunition Percussion Primers (PP-1308), U.S. Army Technical Agent Tank-Automotive and Armaments Command, Armament Research, Development, and Engineering Center

FY 2005 Ongoing Projects

- Distribution and Fate of Energetics on DoD Test and Training Ranges (CP-1155), U.S. Army Corps of Engineers, Engineer Research and Development
- In Situ Bioreduction and Removal of Ammonium Perchlorate (CU-1162), University of California, Berkeley
- Bacterial Degradation of DNT and TNT Mixtures (CU-1212), University of California, Davis
- Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity, and Potential for Ring Fission for Destruction of TNT (CU-1214), Georgia Institute of Technology
- Measurement and Modeling of Energetic Material Mass Transfer to Pore Water (CP-1227), Sandia National Laboratories
- Remediation of Explosives Contaminated Groundwater with Zero-Valent Iron (CU-1232), Oregon Health & Science University
- Sequential Electrolytic Degradation of Energetic Compounds in Groundwater (CU-1234), Colorado State University
- Green Medium Caliber Munitions (PP-1237), U.S. Army Armament Research, Development and Engineering Center
- Enhanced Electromagnetic Tagging for Embedded Tracking of Munitions and Ordnance during Future Remediation Efforts (PP-1272), Battelle Memorial Institute
- Elimination of Chlorine-Containing Oxidizers from Pyrotechnic Flare Compositions (PP-1280), Naval Surface Warfare Center, Crane Division
- Impacts of Fire Ecology Range Management (FERM) on the Fate and Transport of Energetic Materials on Testing and Training Ranges (CP-1305), Battelle Memorial Institute
- Identification of Metabolic Routes and Catabolic Enzymes Involved in Phytoremediation of the Nitro-Substituted Explosives TNT, RDX, and HMX (CU-1317), University of Iowa
- Engineering Transgenic Plants for the Sustained Containment and In Situ Treatment of Energetic Materials (CU-1318), University of Washington
- Genetic and Biochemical Basis for the Transformation of Energetic Materials (RDX, TNT, DNTs) by Plants (CU-1319), Iowa State University
- Medium Caliber Lead Free Electric Primer (LFEP) Program (PP-1331), Naval Air Warfare Center, Weapons Division
- Environmentally Benign Impact Initiated Devices Using Energetic Sol-Gel Coated Flash Metal Multilayers (PP-1362), Lawrence Livermore National Laboratory
- Enhancement of In Situ Bioremediation of Energetic Compounds by Coupled Abiotic/Biotic Processes (CU-1376), Pacific Northwest National Laboratory
- Biodegradation of Nitroaromatic Compounds by Stimulating Humic Substance- and Fe(III)-Reduction (CU-1377), GeoSyntec Consultants, Inc.
- Groundwater Chemistry and Microbial Ecology Effects on Explosives Biodegradation (CU-1378), Shaw Environmental & Infrastructure, Inc.

- Synthesis, Evaluation, and Formulation Studies in New Oxidizers as Alternatives to Ammonium Perchlorate in DoD Missile Propulsion Applications (PP-1403), ATK Thiokol Propulsion
- Robust, Perchlorate-Free Propellants with Reduced Pollution (PP-1404), Naval Air Warfare Center, Weapons Division
- Elimination of Red Water from TNT Manufacture (PP-1408), QinetiQ Ltd.

FY 2005 New Start Projects

- Catalytic Nitration of Toluene (Elimination of Red Water) (PP-1409), U.S. Army Technical Agent Tank-Automotive and Armaments Command, Armament Research, Development, and Engineering Center
- Development of Toxicity Data for Munition Compounds to Support Toxicity Reference Value Derivations for Wildlife (CU-1420), U.S. Army Center for Health Promotion and Preventive Medicine
- Alternative for Perchlorates in Incendiary Mix and Pyrotechnic Formulations for Projectiles (PP-1424), QinetiQ
- Modified Activated Carbon Perchlorate Sorbents – *SEED Project* (CP-1428), Lawrence Berkeley National Laboratory
- Evaluation of Alternative Causes of Wide-Spread, Low Concentration Perchlorate Impacts to Groundwater (CP-1429), GeoSyntec Consultants, Inc.
- Removal of Perchlorate from Water and Wastewater by Catalytic Hydrogen Gas Membrane Systems (CP-1430), University of Delaware
- Biotic and Abiotic Attenuation of Nitrogenous Energetic Compounds (NEC) in Coastal Waters and Sediments (CP-1431), Naval Research Laboratory
- Novel Electrochemical Process for Treatment of Perchlorate in Waste Water – *SEED Project* (CP-1433), Pacific Northwest National Laboratory
- Identification and Characterization of Natural Sources of Perchlorate (CP-1435), U.S. Air Force
- Defining Munitions Constituent (MC) Source Terms in Aquatic Environments on DoD Ranges (CP-1453), Space and Naval Warfare Systems Center

FY 2006 Initiatives

In SERDP's FY 2006 solicitation, four SONs were released that encompass the fate, transport, and remediation of MC, as well as environmentally benign synthesis routes. These SONs address the potential transport and off-site exposure of MC, the containment or treatment of MC, and the potential impacts of remediation efforts.

Range Environmental Fate for Energetic Materials — This SON solicits for the development of environmental data required to characterize (1) energetics residuals that result from the firing of Navy, Air Force, and Marine Corp military munitions; (2) potential releases and the fate of perchlorate on training and testing ranges; and (3) residuals from gun propellants and characterization of leaching rates of contaminants bound in these materials.

Range Environmental Transport Exposure Assessment for Energetic Materials — This SON solicits proposals that develop the following types of tools: (1) screening level tools to accurately predict aquifer and/or surface water vulnerability at training ranges; (2) modeling tools to link data for residual energetics in surface soils with groundwater data so as to aid in management decisions; and (3) tools that will enable

range managers to determine the extent and frequency at which operational ranges must be assessed, cleared, or remediated to protect groundwater based on the types of live-fire activities conducted.

Containment/Treatment of Energetic and Propellant Material Releases on Testing and Training Ranges — The objective of this SON is to develop innovative technologies capable of sustained prevention of migration of surface and near surface soil contamination by MCs (RDX, HMX, TNT, DNT, perchlorate) that may act as a source of groundwater contamination on DoD testing and training ranges. These technologies may employ physical, chemical, or biological containment, immobilization, sequestration, or transformation approaches.

Improved Understanding of the Distribution and Impacts of Subsurface Remedial Amendments in Groundwater — This SON solicits for the development of an understanding of the migration and mixing of amendments injected in the subsurface to enhance the remediation of contaminated groundwater. Contaminants of greatest interest include chlorinated solvents, perchlorate, and munitions constituents. The research should lead to a better understanding of which site-specific factors control the delivery, mixing, and contact of amendments in the subsurface environment, as well as how to effectively monitor these factors to aid in the remedial design process.

Significant Accomplishments

The SERDP project **Impacts of Fire Ecology Range Management (FERM) on the Fate and Transport of Energetic Materials on Testing and Training Ranges** has examined the impact of prescribed burning on the fate and transport of energetic residuals. Led by Battelle Memorial Institute, researchers determined how the relationship between energetic residuals and native plant species can be exploited to enhance the destruction of MCs. Bench-scale experiments were conducted on soil collected from selected ranges to determine rates of decomposition and behavior of energetic materials at temperatures and conditions anticipated in prescribed burns. A full-scale prescribed burn, including pre-burn sampling and installation of surface water traps for subsequent post-burn sampling, commenced at Eglin Air Force Base, Florida. Preliminary results showed that, during the burn, temperatures in the 350°C to 580°C range were achieved at ground surface, resulting in varied levels of TNT and RDX destruction. This information is being analyzed to develop prescribed burning strategies that effectively maximize the destruction of MCs on DoD testing and training ranges.

The SERDP project **Immobilization of Energetics on Live Fire Ranges** has identified and evaluated low-cost additives that can be applied to the surface of active live fire ranges to prevent the migration of energetic compounds to groundwater. Technology researchers from Shaw Environmental and Infrastructure, Inc. developed a sorbent material that immobilizes newly generated MC residues at the soil surface, and a biostimulant that enhances the biotransformation and biodegradation of the explosive compounds before they can migrate into the soil and groundwater (Figure II-1). The research determined that the most effective combination of sorbent and biostimulant was Sphagnum peat moss mixed with crude soybean oil. A .5-inch layer of this material reduced concentrations of TNT, RDX, and HMX in soil by 100%, 60%, and 40%, respectively. A model developed based on these experimental results indicated that a 1-inch layer of this material would reduce the relative mass loading of TNT, RDX, and HMX to soil by 90%, 80%, and 70%, respectively, at an estimated materials cost of \$4,200 per acre. This technology will be demonstrated and validated under SERDP's partner program, ESTCP.

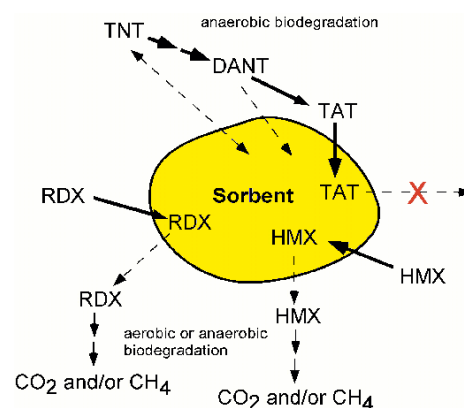


Figure II-1. Conceptual Model of the Role of Sorption and Biodegradation in Preventing the Migration of Energetic Materials to Groundwater.

Pyrotechnics are used in a variety of military applications, including infrared decoy flares and colored signal flares (Figure II-2). In a SERDP project entitled **Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions**, researchers from the Naval Surface Warfare Center-Crane Division (NSWC-Crane) sought to investigate the feasibility of reformulating a variety of pyrotechnic compositions to reduce or eliminate the use of perchlorate as an oxidizer in colored signal flare compositions. In addition to minimizing the contamination caused by perchlorate oxidizers, the project strives to minimize other environmentally objectionable flare combustion products. The project has developed three red flare compositions that are nearing production at the prototype level. In addition, three green flare compositions are tentatively set for scale-up after further optimization. Initial performance evaluations of these new formulations show promising results. The new high-energy metal/alloy fuels being evaluated by this project may have uses in other pyrotechnic or propellant devices and may result in formulations with lower levels of other environmentally objectionable ingredients, such as heavy metals, polyvinyl chloride (PVC), and hexachlorobenzene.



Figure II-2. Infrared Decoy Flare Being Deployed from an F-4 Phantom.

ii. Threatened and Endangered Species

Scope of Problem

The DoD serves as guardian for more than 29 million acres of land in addition to huge offshore operating areas and surrounding airspace over land and sea. DoD is responsible for more TES per acre than any other federal land manager. The protection of these species and their habitats has resulted in restrictions to training. Many of these restrictions result from a lack of information concerning the impact of military operations on the species and/or its habitat. When faced with such a lack of information, the U.S. Fish and Wildlife Service must act conservatively on the side of species protection. A holistic and efficient approach is needed for military installations throughout the United States to integrate the effects of land management, military training demands, and ecosystem responses.

Overview of Investment

SERDP provides installation managers with tools necessary to manage TES on DoD installations without compromising military use of those installations. New tools and methods are required to more rapidly and cost-effectively identify and monitor plant and animal TES, particularly in areas that are inaccessible (e.g., impact zones). Inventories and impact studies are needed for species that are the source of restrictions or have the potential to cause restrictions. In addition, methodologies are needed to manage ranges as entire ecosystems that provide habitat for TES as well as other species. These techniques need to account for land outside the installation that contributes to and impacts the ecosystem on the base. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Development of Bioacoustic Tools for Long-Term, Non-Invasive Monitoring of Threatened and Endangered Birds (CS-1392), University of California, Davis

FY 2005 Ongoing Projects

- Acoustic Monitoring of Threatened and Endangered Species in Inaccessible Areas (CS-1185), Cornell University

- Riparian Ecosystem Management at Military Installations: Determination of Marine Mammals Using an Advanced Digital Acoustic Recording Tag (CS-1186), Oak Ridge National Laboratory
- Impacts of Military Training and Land Management on Threatened and Endangered Species in the Southeastern Fall Line/Sandhills Community (CS-1302), Savannah River Ecology Laboratory
- Regenerating Longleaf Pine on Hydric Soils: Short- and Long-Term Effects on Native Ground-Layer Vegetation (CS-1303), U.S. Department of Agriculture, Forest Service, Southern Research Station
- Toxicological Effects of Smokes and Obscurants on Aquatic Threatened and Endangered Species (CS-1332), U.S. Army Corps of Engineers, Engineer Research and Development Center
- Maximizing Sampling Efficiency and Minimizing Uncertainty in Presence/Absence Classification of Rare Salamander Populations (CS-1393), Oak Ridge National Laboratory
- Automated Acoustic Identification of Bats (CS-1394), Humboldt State University
- Development and Application of a Physiological-Based Framework for Assessing the Biological Significance of Military Activities on Threatened and Endangered Animal Species (CS-1395), Oak Ridge National Laboratory
- Physiological Response and Habituation of Endangered Species to Military Training Operations (CS-1396), U.S. Army Corps of Engineers, Engineer Research and Development Center

FY 2005 New Start Projects

- Advanced Monitoring of Migratory Birds on Military Lands in Desert Environments (CS-1438), University of Wisconsin, Madison
- The Identification of Military Installations as Important Migratory Bird Stopover Sites and the Development of Bird Migration Forecast Models: A Radar Ornithology Approach (CS-1439), U.S. Army Corps of Engineers, Engineer Research and Development Center

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released four SONs for research on TES.

Restoration of Longleaf Pine for Red-Cockaded Woodpecker Habitat — The objective of this SON is to develop scientifically based management protocols for longleaf pine restoration while maintaining or enhancing the habitat for the red-cockaded woodpecker (RCW). The key is to conduct landscape-scale restoration of longleaf pine in regions currently dominated by other species such as loblolly pine.

Examination of Endangered and Threatened Species Habitat Fragmentation Issues On and In the Vicinity of DoD Installations — This SON seeks methods to identify the most ecologically important land parcels in the vicinity of DoD installations. Once these parcels are identified, DoD can work with other stakeholders to provide land protection for long-term species conservation benefits and avoidance of additional military training restrictions.

Methodology for Scientifically-Defensible Population Recovery Goals for Listed Species — This SON solicits for the development of risk assessment methods and models to define scientifically based recovery goals for listed TES. This work is expected to provide a scientific foundation for establishing TES recovery plans. These recovery plans then will become an integral part of the Integrated Natural Resources Management Plan (INRMP) on DoD installations.

Innovative Conservation Initiatives in the Areas of Integrated Natural Resources Management, Invasive Species Control, and Cultural Resources Management — The objective of this SEED SON is to develop innovative approaches for analysis, tools, and techniques that can assist DoD natural resource managers. SERDP seeks proposals that (1) promote natural habitat restoration and protection, thereby preventing the listing of additional plant and animal species; (2) enhance the accessibility, evaluation, and use of existing inventory data; and (3) encourage creative partnerships to promote natural resources management on DoD lands.

Significant Accomplishments

In response to the need for a more holistic approach to habitat management, the SERDP project **Impacts of Military Training and Land Management on Threatened and Endangered Species in the Southeastern Fall Line/Sandhills Community** is evaluating the effects of forest management practices and military training activities on the Fall Line sandhills ecoregion in the Southeastern United States and the suite of TES therein (Figure II-3).



Figure II-3. The Gopher Tortoise Is One of More than Twenty Plant and Animal TES that Have Habitat in the Sandhills Communities of the Fall Line Ecoregion.

For the three Fall Line sites (Fort Benning, GA; Fort Gordon, GA; and the DOE Savannah River Site, SC), researchers from the Savannah River Ecology Laboratory developed metrics for discriminating sandhills communities from surrounding pine woodlands. Statistical analyses then were conducted to relate these unique sandhills communities with spatial information (e.g., soil types, false-color infrared aerial photographs, and Landsat Enhanced Thematic Mapper satellite images). With this baseline information, populations of ten TES sandhills plant species were surveyed and habitat conditions characterized to develop species-specific habitat models.

A forest understory removal experiment including burning, mechanical removal, and the use of herbicides evaluated the effects of specific management practices for promoting habitat of the red-cockaded woodpecker in sandhills communities. These field surveys and experiments are being used to quantify the impacts of forest management practices on sandhills communities and TES. Probability-based habitat models, nested within landscape models, will be used to identify areas with habitat conditions that can support multiple species or habitat conditions where conflicts among species may occur. The results of this research will provide military land managers along the Fall Line ecoregion with information that more effectively protects sandhills communities and their TES, while allowing continued military training with minimal restrictions.

iii. Marine Mammals

Scope of Problem

There is increasing concern that man-made sound may have detrimental effects on marine mammals. Anthropogenic ocean noise is associated predominantly with commercial shipping, but a wide variety of other noises such as explosive sources, sonar, and seismic exploration also may affect marine mammals. These noise sources have contributed to a dramatic increase in the ambient sound field in the world's oceans. Marine mammals are protected under the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and National Environmental Protection Act (NEPA). There is some concern that the use of naval sonar may be harming marine mammals, especially deep-diving whales. The Navy has a high priority requirement for a scientific understanding of the potential impacts of sonar on marine

mammals as well as data on the locations and seasonal population densities of marine mammals within areas of frequent naval operations.

Overview of Investment

SERDP provides scientific information necessary to understand and predict the impact of military training operations on marine mammals. In light of uncertain impacts of military operations on marine resources, a commonly employed strategy for protection is to avoid contact with them. This requires the ability to detect and monitor the location of marine mammals in real time. An unambiguous understanding of the effects of military operations on specific organisms also is required to develop either operational guidelines or new mitigating technologies. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off-Shore Range (CS-1189), University of California, San Diego

FY 2005 Ongoing Projects

- Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag (CS-1188), Woods Hole Oceanographic Institution
- Application of ROV-Based Video Technology to Complement Coral Reef Resource Mapping and Monitoring (CS-1333), University of Miami
- Analysis of Biophysical, Optical, and Genetic Diversity of DoD Coral Reef Communities Using Advanced Fluorescence and Molecular Biology Techniques (CS-1334), Rutgers, The State University of New Jersey
- Predictive Spatial Analysis of Marine Mammal Habitats (CS-1390), Duke University, Marine Laboratory
- Predictive Modeling of Marine Mammal Density from Existing Survey Data and Model Validation Using Upcoming Surveys (CS-1391), National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center

Significant Accomplishments

Under the direction of the Woods Hole Oceanographic Institution, the SERDP project **Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag** is evaluating the feasibility of monitoring marine mammals throughout their range of behavior. This project has developed and deployed a compact electronic tag that can be temporarily attached to whales to record their exposure to acoustic signals and their vocal or behavioral responses to these exposures (Figure II-4). To date, five tags have been attached to Cuvier's beaked whales (*Ziphius cavirostris*) for a total of 17 deep foraging dives in 38 hours of recording. This represents a major accomplishment, as this species had never before been tagged. The data collected from these tags provides the first detailed look at the behavior of these whales while they are submerged. Application of this technology will lead to a clearer understanding of the response of marine mammals to sound in the ocean. Foraging sounds used by the whales were also quantified, and vocal behavior was related to



(NMFS Permit # 981-1578-0)

Figure II-4. The Digital Acoustic Recording Tag Developed by Woods Hole Oceanographic Institute.

dive behavior. The database of whale vocalizations from tag recordings will improve the detection and identification of marine mammal species using passive acoustic detection systems.

iv. Invasive Species

Scope of Problem

The proliferation of invasive or nonindigenous plant and animal species is a recognized threat to the ecology of terrestrial and aquatic environments worldwide. Specific to DoD, invasive species such as the star thistle are impacting the ability of ranges to support training operations. Consequently, it is imperative that military installations not only take proactive measures to prevent the introduction of invasive species on DoD lands and in U.S. waters, but also provide for their control. As the awareness and severity of this threat continues to grow, installations must identify, locate, and remove or control these nonindigenous species in order to ensure the long-term sustainability of ranges and the overall health of the environment. Historically, however, measuring, mapping, monitoring, and controlling invasive species has been a very costly and time-consuming process.

Overview of Investment

Investments in the area of invasive species span the Compliance and Conservation thrust areas. SERDP seeks to provide DoD land managers with the tools to effectively monitor and control invasion by non-native nuisance plant and animal species. To manage invasive species, one must be able to rapidly and cost-effectively detect their presence over large tracts of land in widely varying terrain. In addition, technologies to detect and control invasive species inadvertently carried by DoD platforms are needed to prevent the unintended introduction of these species to lands and waters. Technologies or techniques also are required to eliminate or control invasive species infestations, while minimizing harmful impacts to indigenous species and habitats. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation (CS-1143), University of California, Davis
- Integrated Control and Assessment of Knapweed and Cheatgrass on DoD Installations (CS-1145), Colorado State University
- Harmful Algae, Bacteria, and Fauna Transported by Department of Defense Vessels (CP-1244), North Carolina State University
- Characterization of Aquatic Non-Indigenous Species for Department of Defense Vessels (CP-1245), Naval Surface Warfare Center, Carderock Division

FY 2005 Ongoing Projects

- Allelochemical Control of Non-Indigenous Invasive Plant Species Affecting Military Testing and Training Activities (CS-1388), Colorado State University
- Effectiveness of Selected Native Plants as Competitors with Non-Indigenous and Invasive Knapweed and Thistle Species (CS-1389), University of Wyoming

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released one SEED SON concerning invasive species.

Innovative Conservation Initiatives in the Areas of Integrated Natural Resources Management, Invasive Species Control, and Cultural Resources Management — The objective of this SON is to develop innovative approaches for analysis, tools, and techniques that can assist DoD natural resource managers. Habitat enhancement, through control of exotic pests and promotion of natural species, can minimize disturbance of natural landscapes and increase vegetative cover, thereby controlling a growing threat to environmental security while improving training conditions.

Significant Accomplishments

To address the problem of nonnative plants on land, researchers from the University of California, Davis working on the SERDP-funded project **Application of Hyperspectral Techniques to Monitoring & Management of Invasive Weed Infestation** have successfully developed and integrated image processing and geographic information system (GIS) methods that allow mapping of invasive species using hyperspectral remote sensing data. This technique involves taking a collection of photographs across a number of spectral bands and examining each pixel's spectral response. These responses are indicative of that area's vegetation and can reveal areas of invasive weed infestation (Figure II-5). New analysis tools were developed to characterize plant habitats and identify weeds using hyperspectral imaging. With the new tools developed under this project, installation managers have a timely and cost-effective means to develop accurate maps of invasive species within their boundaries and can more effectively select invasive species control approaches. Initial estimates indicate that remote sensing surveys can dramatically increase the survey area—square miles versus acres—while reducing associated time and costs by more than 90%. This project was recognized and awarded the FY 2004 SERDP Conservation Project-of-the-Year Award at the *Partners in Environmental Technology Symposium & Workshop* held November 30 – December 2, 2004.

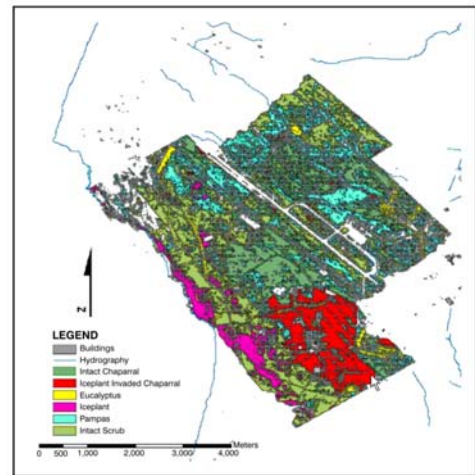


Figure II-5. Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Image of Vandenberg AFB Depicts Areas of Invasive Invasions.

In the aquatic environment, nonindigenous species can be transported on the hulls of ships and by the release of organisms in ship's ballast water during deballasting operations. The vast majority of current research on the transport of aquatic nonindigenous species has been carried out on commercial vessels. However, the DoD also operates a large fleet with the potential to introduce invasive aquatic organisms. Two SERDP projects collaboratively have developed a better understanding of the role that DoD operations may play in the introduction of invasive aquatic species. Led by the Naval Surface Warfare Center-Carver Division, the SERDP project **Characterization of Aquatic Non-Indigenous Species for DoD Vessels** quantified the spatial and temporal variation of the abundance and diversity of organisms present in the ballast tanks. Researchers related these findings to the variation in the physical and chemical characteristics of the ballast water and ballast management practices. In another SERDP project **Harmful Algae, Bacteria, and Fauna Transported by DoD Vessels**, researchers from North Carolina State University developed innovative sampling and handling procedures to (1) analyze ballast water, focusing on harmful algae, planktonic bacteria, and microfauna, and (2) determine the types and quantities of harmful microbial organisms transported by DoD vessels that may pose environmental or public health risks. Samples were collected and analyzed from 28 vessels, and the results indicate that Navy requirements to perform mid-ocean ballast tank water exchanges greatly diminishes the incidence and number of foreign organisms in ballast water.

v. Air Quality

Scope of Problem

Military ranges are under increasing public scrutiny with respect to potential environmental hazards to nearby communities. The military's goal to "train as we fight" is being challenged by various encroachment issues, which must be resolved in order to sustain the military's ability to conduct realistic training. Such training activities are scrutinized for contributing to local and regional air quality problems. Noncompliance with existing and proposed standards and regulations can result in the curtailment of military testing and training activities, ultimately affecting mission readiness.

In the context of sustainable training and testing ranges, one issue of concern is fugitive dust emissions. Fugitive dust consists mainly of small airborne particulate matter (PM) less than 2.5 microns in size (PM_{2.5}) that may not originate from a specific point source. Military activities on DoD installations in the southwestern United States are potentially large contributors of wind-blown dust due to the presence of large expanses of desert soils on training and testing ranges. Fugitive dust has a known impact on human health, and dust obscures visibility that can impact military training.

Overview of Investment

SERDP is developing new scientific information on air emissions from military platforms and weapons as well as from operations on training ranges. Accurate emissions factors for military platforms must be developed for varying atmospheric conditions and terrain. There is also a need for scientific knowledge of emissions fate and the ability to predict the transport of emissions. Technologies also are required to reduce, eliminate, or control the generation of air emissions from military operations. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Investigations of Improvements in Environmental Accountability, Safety, Process and Training for New Technologies and Deconstruction Methodologies (CP-819), National Environmental Education & Training Center
- Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations (CP-1191), Desert Research Institute
- Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion (CP-1195), Pacific Northwest National Laboratory
- A Field Program to Identify TRI Chemicals and Determine Emission Factors From DoD Munitions (CP-1197), Battelle Memorial Institute

FY 2005 Ongoing Projects

- Characterization of PM_{2.5} Dust Emissions from Training/Testing Range Operations-9 (CP-1190), University of Utah
- Temporal and Modal Characterization of DoD Source Air Toxic Emission Factors (CP-1247), U.S. Environmental Protection Agency, National Risk Management Research
- Development and Validation of a Predictive Model to Assess the Impact of Coastal Operations on Urban Scale Air Quality (CP-1253), Desert Research Institute
- Characterization of Off-Road Diesel Emissions of Criteria Pollutants (CP-1336), Desert Research Institute

FY 2005 New Start Projects

- Particulate Matter Emissions Factors for Dust from Unique Military Activities (CP-1399), Kansas State University
- Development of Emission Factors for Dust Generated by Unique Military Activities (CP-1400), U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory
- A Comprehensive Program for Measurement of Emissions From Military Aircraft (CP-1401), Oak Ridge National Laboratory
- Development of Emission Factors for Particulate Matter, Nitrogen Oxides, and Air Toxic Compounds from Military Aircraft (CP-1402), Battelle Memorial Institute
- Evaluation of Ground Vibrations Induced by Military Noise Sources (CP-1410), U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory

Significant Accomplishments

Two SERDP-funded projects, **Characterization of PM_{2.5} Dust Emissions from Training/Testing Range Operations** and **Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations**, collaboratively developed a fundamental scientific understanding of dust generation and transport from DoD military vehicles on unpaved surfaces—an essential first step to provide a more accurate and realistic assessment of DoD's impact on regional air quality. This understanding should lead to enhancement of the existing EPA method to estimate dust emission factors and cost-effective strategies to mitigate dust emissions from DoD activities.

Researchers from the University of Utah and Desert Research Institute revised previous assumptions by quantifying actual dust emissions from a variety of wheeled military vehicles and developing methods to track military vehicle dust sources, as well as other fugitive dust sources. The successful studies conducted by these two projects support the hypothesis that while these specific DoD training activities may contribute to local PM/visibility issues, they may not be a major source of regional dust on an annual average time scale. In fact, windy atmospheric conditions and the presence or absence of disturbed soils are primarily responsible for dust generation and transport on a regional basis. This information will be used to develop strategies to mitigate these emissions and help DoD maintain compliance with air quality regulations while having a positive impact on readiness. These projects were jointly awarded the FY 2004 SERDP Compliance Project-of-the-Year Award at the *Partners in Environmental Technology Symposium & Workshop* held November 30 – December 2, 2004.

A related issue of public concern is the potential environmental consequences caused by emissions from the use of munitions. The Emergency Planning and Community Right-to-Know Act (EPCRA) requires industry and government agencies to report emissions of chemicals listed on the Toxic Release Inventory (TRI). DoD testing and training ranges need reliable data on air emissions of TRI chemicals from munitions activities to (1) meet EPCRA reporting requirements and/or (2) demonstrate that emissions are below *de minimis* concentrations and can be excluded from EPCRA reporting requirements. To meet this need, the SERDP project **A Field Program to Identify TRI Chemicals and Determine Emission Factors from DoD Munitions Activities** developed, evaluated, and applied

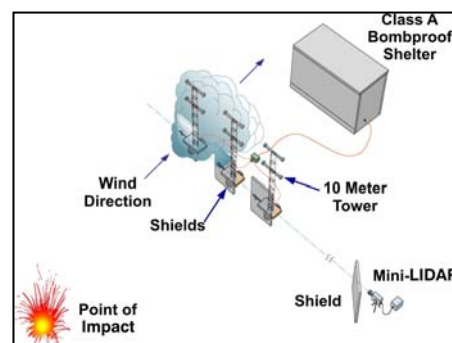


Figure II-6. Plume Measurement During POI Field Campaign.

approaches to determine the TRI chemical emissions discharged by munitions under realistic conditions. Researchers from Battelle Memorial Institute identified 124 TRI chemicals or chemical groups as potentially emitted from munitions. Point of impact (POI) tests measured the concentrations of munitions chemicals in a relatively small, moving cloud of emissions that successfully measured TRI chemicals with sufficient sensitivity to calculate emissions factors (Figure II-6). These results will allow the military to address the potential toxic release reporting requirements as well as hazards to military personnel.

vi. Encroachment

Scope of Problem

When most of DoD's training installations were established, they were located in rural areas far from urban centers. In many cases, communities developed and grew near the base simply because the base existed. Today, that growth is becoming problematic. According to the Government Accounting Office, during the last 10 years, 80% of DoD installations are being affected by urban growth that exceeds the national average rate of 8% growth. More than 30% of DoD installations have experienced double the national growth rate within their communities. As communities grow toward the boundaries of ranges and installations, land use incompatibilities emerge. These incompatibilities can compromise the health, safety, and welfare of both military and civilian communities. Often lawsuits are filed against installations. Outcomes include curtailed range operations (such as aircraft operations or weapons firing) or judgments that provide compensation to residents who successfully argue reduced property value. When land use conflicts emerge, the military often loses full use of its ranges. The ability to understand and predict how patterns of land use in the surrounding community may change as well as understanding how those changes in land use will impact the mission of the installation is vital.

Overview of Investment

SERDP provides the tools for installation managers to understand and predict the impact of changing land use and demographics in the communities surrounding the installation. Assessing land uses for compatibility with the military mission is critical. To this end, predictive models are required. With these models, the installation can work with the local community to develop science-based, rational plans for compatible growth that will accommodate the needs of the installation and the community. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Detection and Identification of Archaeological Sites and Features Using Radar Data (CS-1260), Jet Propulsion Laboratory
- New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resources Identification and Evaluation (CS-1263), University of Arkansas, Center for Advanced Spatial Technology

FY 2005 Ongoing Projects

- The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustainable Military Communities (CS-1257), U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory
- A Regional Simulation to Explore Impacts of Resource Use and Constraints (CS-1259), Oak Ridge National Laboratory

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released one SEED SON concerning encroachment.

Innovative Conservation Initiatives in the Areas of Integrated Natural Resources Management, Invasive Species Control, and Cultural Resources Management — The objective of this SON is to develop innovative approaches for analysis, tools, and techniques that can assist DoD natural resource managers. A suite of integrated, cutting-edge methods and techniques that improve traditional cultural resources survey and assessment methods is required to improve both the management efficiency and cost of cultural resource management practices on DoD and DOE lands.

Significant Accomplishments

To address concerns surrounding encroachment, SERDP is funding a project entitled **RSim: A Regional Simulation to Explore Impacts of Resource Use and Constraints**. A user-friendly regional simulator (RSim) will integrate the prediction of the environmental effects of on-base training and testing with off-base development. The computer simulation for this project builds on the Land-Use Change Analysis System (LUCAS) model. LUCAS was tailored for modeling land-use change, resource use, and land management policies for the Fort Benning region in southwest Georgia.

RSim is being constructed by researchers at Oak Ridge National Laboratory to integrate land-use changes with the ecological effects of changes in noise, water and air quality, and habitats for species of special concern. RSim is designed to project land-use changes and their impacts for the five counties surrounding Fort Benning (Figure II-7). The effects of building a 1,100-acre Digital Multipurpose Range Complex are being modeled and monitored to identify the potential effects on the environment as well as the urbanization effects outside of Fort Benning. Ultimately, the RSim will be web-enabled and made available DoD-wide, and the model will be provided in a gaming mode so that users can explore repercussions of military and land-use decisions. RSim will allow consideration of several criteria at the same time, including air, water, noise, and species.

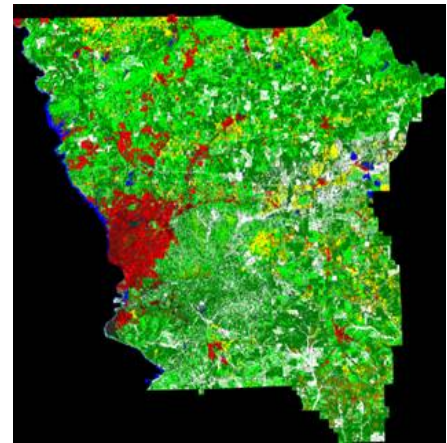


Figure II-7. Projected Growth Due to New Road-Influenced Urbanization at Fort Benning, Georgia.

vii. Carrying Capacity

Scope of Problem

The DoD's mission requires the use of maneuver and testing land to maintain readiness through realistic training opportunities. Repeated use of heavy vehicles such as tanks can have serious impacts on the land, potentially resulting in the loss of vegetation, soil destabilization, erosion, and invasion by non-native species. These impacts affect the sustainability of military land and adjacent waters and the ability to meet mission requirements.

Carrying capacity is defined as the ability of the land to support certain operations without suffering permanent degradation. Carrying capacity is a function of many diverse factors including the terrain, soil structure, soil moisture, climate, and vegetative cover, which vary from location to location. The carrying capacity of any particular parcel of land also will vary with season and from year to year. Training activities have a significant impact on carrying capacity. A given parcel of land will have a higher carrying capacity for light infantry training consisting of soldiers on foot than it would for heavy armor

training with Abrams tanks. Quantitative measures of the impacts of these types of military operations are critical to monitoring and predicting the carrying capacity.

Overview of Investment

Investments in the area of carrying capacity span the Conservation and Compliance thrust areas. SERDP provides technologies for land managers to determine the carrying capacity of the training and testing ranges as well as the tools to manage ranges to preserve that carrying capacity. It is important to develop algorithms and quantitative measures of all of the factors that impact carrying capacity. Technologies and techniques for cost-effective restoration of carrying capacity also are required. New techniques that limit environmental damage on ranges will mitigate the need and/or extent of restoration. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2005 Ongoing Projects

- SERDP Ecosystems Management Project (SEMP) (CS-1114), U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory
- An Integrated Approach to Understand Relationships Between Shallow Water Benthic Community Structure and Ecosystem Function (CS-1335), Virginia Institute of Marine Science
- Assessing the Impact of Maneuver Training on NPS Pollution and Water Quality (CP-1339), Kansas State University, National Institute for Land Management & Training
- Development of an Adaptive Framework for Management of Military Operations in Arid/Semi-Arid Regions to Minimize Watershed and Instream Impacts from Non-Point Pollution (CP-1340), Pacific Northwest National Laboratory
- SERDP's Defense Coastal/Estuarine Research Program (DCERP) (CS-1413), Naval Facilities Engineering Service Center

Significant Accomplishments

The SERDP project **An Integrated Approach to Understand Relationships between Shallow Water Benthic Community Structure and Ecosystem Function** is evaluating the impacts of military activities on the function of the shallow-water ecosystem of the nation's largest estuarine system, the Chesapeake Bay. Specifically, researchers from the Virginia Institute of Marine Science are assessing the composition and integrity of benthic plant and animal communities in aquatic environments adjacent to military and non-military sites. A Benthic Index of Biotic Integrity (B-IBI) is calculated to assess the health of benthic communities at military installations. Correlation is being evaluated among B-IBI metrics, food web structure, primary production, respiration, and nitrogen cycling along gradients of impairment in the Chesapeake Bay.

In 2003, researchers sampled high mesohaline/polyhaline sites in the southern Chesapeake Bay, including a relatively pristine reference site at Langley Air Force Base, Virginia, and a highly impacted site in the Elizabeth River, Virginia (Figure II-8). Preliminary analyses of both current and historic water quality and sediment quality data suggest that the B-IBI is a sensitive indicator of aquatic ecosystem



Photo courtesy of NASA/ GSFC/JPL, MISR Science Team

Figure II-8. The Benthic Index of Biotic Integrity (B-IBI) Metrics Are Being Applied to Assess Benthic Community Health in Varying Regions of the Chesapeake Bay.

disturbance. B-IBI scores point to clear relationships between measures of benthic ecosystem structure and function along a gradient of ecosystem disturbance (from low to high). Results such as these will improve and expand existing tools used by DoD installation managers and scientists in managing and restoring estuarine ecosystems.

viii. Noise

Scope of Problem

The availability of airspace for military training and operations is a serious concern for the DoD. Noise is often the dominant environmental impact of flight operations. In its June 2000 report, the Joint Strike Fighter (JSF) Overarching Integrated Product Team raised concerns over potential noise emissions and noise regulations threatening to impact future JSF operations. Furthermore, military installations that were originally located in remote areas far from public view are now in the midst of densely populated areas, so noise caused by live fire training and operations may be considered increasingly incompatible with nearby communities.

The ability to accurately model noise associated with flight operations has allowed the DoD to provide legally defensible noise assessments of its operations and to comply with requirements of the NEPA. However, the current environmental noise models used by the DoD are not appropriate for the new generation of fighter aircraft with high performance engines and vectored thrust capabilities. These shortcomings have the potential to lead to restrictions in flight operations at airbases and within training airspaces. New noise models that take advantage of today's computational capabilities are needed to assess potential restrictions imposed on training activities and to protect bases and airspace for training.

Overview of Investment

SERDP provides tools for predicting and monitoring noise levels from military operations and for understanding and mitigating impacts to humans, animals, and structures. Most current noise models have limitations and are in need of refinement given new aircraft and weapons. Noise complaints from the surrounding communities is the most significant issue impacting military operations. Another source of restrictions to training occurs due to the presence of animal species that are sensitive to noise; however, there is often limited scientific knowledge of the actual impacts of noise on the species of concern. Further development and refinement of noise models is needed to calibrate and predict how noise impacts man-made structures above the ground as well as how noise travels from the air into and through the ground and the potential for damage to the foundations of those structures. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2005 Ongoing Projects

- Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessment (CP-1304), Wyle Laboratories, Inc.
- Airborne Weapons Noise Prediction Model (CP-1397), Wyle Laboratories, Inc.
- Prediction Model for Impulsive Noise Impacts on Structures (CP-1398), Wyle Laboratories, Inc.

FY 2005 New Start Projects

- Impulse Noise Bearing and Amplitude Measurement and Analysis System (BAMAS) (CP-1427), Applied Physical Sciences Corporation

- Development of Metrics for Identifying Military Impulse Noise Sources – *SEED Project* (CP-1436), University of Pittsburgh

Significant Accomplishments

Under SERDP project **Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessment**, a U.S. Air Force (USAF)/National Aeronautics and Space Administration (NASA) aircraft noise simulation model is being updated by Wyle Laboratories, Inc. to account for noise characteristics of the new generation of fighter aircraft. Laboratory experiments have provided detailed information on the complex near-field characteristics of jet noise for a range of operating conditions that cannot be efficiently measured in the field. This information has been combined with full-scale field data and validated nonlinear sound propagation algorithms to replace the former linear versions. The result is an advanced noise simulation model that allows dynamic visualization of the impacts of high-performance jet engines and vectored-thrust aircraft such as the F-22 and JSF.

SERDP also is sponsoring two other noise projects led by Wyle Laboratories, Inc. The **Airborne Weapons Noise Prediction Model** project is integrating noise data from airborne weapon systems into an existing noise propagation model, while the **Prediction Model for Impulsive Noise Impacts on Structures** project is assessing the impulsive noise from weapons. Together, these projects are creating a validated model for high performance aircraft noise and other high intensity noise sources and yielding robust noise analyses able to withstand scrutiny in coming years.

C. Reducing Current and Future Liabilities

Current and future environmental liability for the Department involves the remediation of past practices and the elimination or mitigation of future issues. These liabilities frequently are associated with the industrial processes required to build, maintain, and repair military hardware. In addition, there are significant issues associated with the operation of platforms and use of weapons. The preferred means to address these issues is to view systems in a total life-cycle management framework and to eliminate hazardous and toxic materials when possible. Future liabilities have been significantly reduced through the development and application of new, advanced, environmental technologies that address UXO, chlorinated solvents, heavy metals, air emissions, and hazardous materials/solid waste. Opportunities abound as well for further cost reductions.

i. Unexploded Ordnance

Scope of Problem

UXO presents a major challenge to DoD in its effort to conduct military munitions response actions at sites other than operational ranges. It also is a challenge for active military installations seeking to manage their operational ranges as sustainable assets. There are 3,398 military munitions response sites at active and base realignment and closure (BRAC) installations and formerly used defense site (FUDS) properties, encompassing more than 27 million acres of land. The current projected estimate to cleanup this land is approximately \$20 billion. The UXO characterization and remediation activities conducted at DoD sites using traditional technology is extremely expensive and often yields unsatisfactory results, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and nonhazardous items. Field experience indicates that more than 99% of objects excavated in the course of a UXO remediation are found to be nonhazardous items (i.e., false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating these nonordnance items. New technologies capable of detecting UXO with high detection

rates and low false alarm rates are required to reduce drastically the cost of site characterization and cleanup. UXO cleanup, at the current rate of progress, will require decades to complete.

Technical capability has advanced beyond “mag and flag” for open terrain; digital sensors paired with modern GPS navigation collect data systematically, providing a map of sensor responses. Such systems have led to improvements in detection and reduction in false alarms at simple sites. However, advances are still needed to: (1) improve detection and discrimination under a variety of operational conditions; (2) develop sampling techniques for wide-area surveys; (3) improve vehicle and man-portable surveys; and (4) evaluate individual items for their explosive hazard.

Overview of Investment

SERDP develops effective and efficient technologies, processes, and procedures for the reliable and cost-effective environmental remediation of UXO—while pursuing technologies that reduce or eliminate the generation of UXO. To locate concentrations of UXO and reduce the area required for intensive and intrusive surveys, wide-area screening systems are needed to identify with high confidence the boundaries of contaminated areas and to certify clean areas.

Production surveys currently use single or multisensor arrays to collect the data used to detect and locate UXO both on land and underwater. These data then are analyzed using computer modeling and simulation software to identify UXO. Reduction in false alarm rates, increased detection probabilities, and better characterization of the subsurface UXO are needed.

Standards and protocols focused on the collection, management, and evaluation of geophysical data are required for evaluating UXO technology performance and selecting the most effective technologies for individual sites. Standard software and visualization tools are needed to provide regulatory and public visibility to and understanding of the analysis and decision process made in UXO remediation activities. Statistical uncertainties in any subsampling protocol and continued sensor imperfection point to a need to quantify unavoidable risk and make defensible decisions in identifying UXO.

Systems also are needed to safely remove, render safe, and dispose of UXO. The ultimate objective for heavily contaminated areas would be a system that excavates the soil, sorts the explosive ordnance and breaks it down into inert components for scrap disposal. This scrap then must be tested for explosive residue for remediation prior to recycling.

Due to their condition, surface and excavated inert items such as practice bombs normally must be treated as containing high explosives or other hazardous material because there are no means of outwardly distinguishing them from actual UXO. These items generally are not determined to be inert until they have been detonated where they were found. SERDP is examining technologies that will permit the external discrimination from inert practice munitions from live rounds.

Detection and discrimination of UXO is the most difficult aspect of range clearance. The development of technologies that will permit the easy location and identification of UXO items, possibly via unique “tags” is desirable. Such a tag would alert the range operator to the existence, type, and location of an unexploded munition. The tag would need to be designed to be destroyed when a munition operates properly. Also, there may be types of training that require a weapon to be fired but do not require the use of live munitions. The development of inert ordnance that is easily recognizable, disintegrates, or is reusable and has no adverse environmental impact is needed. Other options include further reducing the dud or partial detonation rate of munitions. The following initiatives have been funded by SERDP to accomplish the Program’s objectives in the area of UXO:

FY 2004 Completed Projects

- Detection and Classification of Buried Metallic Objects (UX-1225), Lawrence Berkeley National Laboratory
- Physics-Based Modeling and Signal Processing for SAR Detection of Former Bombing Ranges and Burial Pits (UX-1283), Duke University
- UXO Classification Using a Static TEM Antenna Array (UX-1309), Zonge Engineering, Inc.
- Efficient, Realistic, Physics-Based Modeling for Buried UXO Based on Time-Domain Electromagnetic Scattering Signatures (UX-1311), BAE Systems, Inc.
- Multi-Sensor CSEM Technology for Buried Target Classification (UX-1312), Texas A&M University
- Quantification of UXO Variability for Target Discrimination (UX-1313), AETC, Inc.
- Advanced Magnetic System for UXO Detection and Discrimination (UX-1327), Quantum Magnetix, Inc.
- Improved Analysis Algorithms for UXO Filler Identification (UX-1383), SAIC
- Determining the Properties and Capabilities of an Existing Experimental Large Loop EM61 Underwater UXO Detector (UX-1385), Dillon Consulting, Ltd.
- Neutron Spectrometry for Identification of Filler Material in Recovered UXO (UX-1386), Pacific Northwest National Laboratory
- Seismic Imaging of UXO-Contaminated Underwater Sites (UX-1387), Lawrence Berkeley National Laboratory

FY 2005 Ongoing Projects

- Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites (UX-1281), Duke University
- UXO Discrimination in Cases with Overlapping Signatures (UX-1282), U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory
- Standardized UXO Technology Demonstration Sites Program (UX-1300), U.S. Army Environmental Center
- Sensor Orientation Effects on UXO Geophysical Target Discrimination (UX-1310), U.S. Army Environmental Center
- Three-Dimensional Steerable Magnetic Field (3DSMF) Sensor System Classification of Buried Metal Targets (UX-1314), Johns Hopkins University, Applied Physics Laboratory
- EMI Sensor Optimized for UXO Discrimination (UX-1315), Naval Research Laboratory
- Development and Evaluation of an Airborne SQUID-Based Magnetic Gradiometer Tensor System for Detection, Characterization, and Mapping of Unexploded Ordnance (UX-1316), Oak Ridge National Laboratory
- Broadband Electromagnetic Detection and Discrimination of Underwater UXO (UX-1321), Geophex, Ltd.
- On-Time 3D Time-Domain EMI and Tensor Magnetic Gradiometry for UXO Detection and Discrimination (UX-1328), U.S. Geological Survey

- Modeling for Sensor Evaluation in Underwater UXO Test Beds (UX-1329), Naval Surface Warfare Center, Dahlgren Division, Coastal Systems Station
- Model-Based, Robust Methods for UXO Discrimination from Time and Frequency Domain EMI (UX-1379), Northeastern University
- Advanced UXO Discrimination Using Magnetometry: Understanding Remanent Magnetization (UX-1380), Sky Research, Inc.
- Handheld UXO Sensor Improvements to Facilitate UXO/Clutter Discrimination (UX-1381), AETC, Inc.
- Acoustic Identification of Filler Materials in Unexploded Ordnance (UX-1382), University of Denver
- Analysis and Processing of PELAN Data (UX-1384), Naval Explosive Ordnance Disposal Technology Division
- Improving Detection and Discrimination of UXO in Magnetic Environments (UX-1414), Colorado School of Mines

FY 2005 New Start Projects

- Characterization of Freshwater Electromagnetic Subbottom Sediment Properties and Target Responses for Detection of UXO with Ground-Penetrating Radar (UX-1440), U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory
- UXO Navigation Technology (UX-1441), Sky Research, Inc.
- Statistical and Adaptive Signal Processing for UXO Discrimination for Next-Generation Sensor Data (UX-1442), Duke University
- New Man-Portable Vector (MPV) Time Domain Electromagnetic Induction Sensor and Physically Complete Processing Approaches for UXO Discrimination Under Realistic Field Conditions (UX-1443), U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory
- Compact, Low-Noise Magnetic Sensor with Fluxgate (DC) and Induction (AC) Modes of Operation (UX-1444), QUASAR, Inc.
- Electromagnetic 3-Component Array Sensors for UXO Discrimination (UX-1445), Flagstaff GeoConsultants Pty Ltd.
- A Unified Approach to UXO Discrimination Using the Method of Auxiliary Sources – *SEED Project* (UX-1446), Sky Research, Inc.
- A New Sensor Based Upon a Rotating-Coil Electromagnetic Induction Concept – *SEED Project* (UX-1447), AETC, Inc.
- Moving Belt Metal Detector – *SEED Project* (UX-1448), Johns Hopkins University, Applied Physics Laboratory
- Monte Carlo Engine for Electromagnetic Induction Analysis – *SEED Project* (UX-1449), AETC, Inc.
- Frequency Domain Electromagnetic Sensor Array Development – *SEED Project* (UX-1450), AETC, Inc.
- Empirical Corrections to Dipole Model – *SEED Project* (UX-1451), AETC, Inc.

- Intra-Inversion Filtering for Use of Magnetic Fields to Locate and Characterize Magnetic Dipoles for UXO Cleanup – *SEED Project* (UX-1452), Rene Geophysics, Inc.
- Use of Target Shape and Size in Classification of UXO in Survey Data (UX-1455), AETC, Inc.

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released five SONs that address various aspects of improving the detection and discrimination of UXO on land and underwater.

Innovative Technology for Wide Area Assessment of Sites Potentially Contaminated with Unexploded Ordnance — This SON solicits proposals to develop a next generation of wide-area UXO assessment technologies. Areas of interest include sensor hardware and phenomenology, signal processing, advanced platforms, and systems design and integration that will lead to advances in support of wide area assessment. These advances will provide a new capability to cost effectively characterize sites potentially contaminated with UXO, identify areas where no further action is required, and provide sufficient information to prioritize areas requiring cleanup.

Development of Handheld and Man-Portable Platforms Supporting Geophysical Surveys of Unexploded Ordnance Contaminated Sites — Man-portable and hand-held platforms generally are used on sites characterized by difficult terrain and vegetation conditions. This SON seeks to provide a new capability to cost effectively characterize and remediate UXO sites, resulting in improved site coverage, improved discrimination, significant cost savings, and increased capabilities to deploy advanced technologies and signal processing algorithms to a wide diversity of site conditions requiring handheld or man-portable platforms.

Sensor Phenomenology of Unexploded Ordnance in Underwater Environments — Modern geophysical surveying techniques can effectively characterize sites potentially contaminated with UXO on land; however, many sites contain UXO underwater, where the environment restricts access to and may significantly impact the performance of established and emerging characterization technologies. Areas of interest for this SON include UXO target signature phenomenology, background clutter signature phenomenology, and impacts of the aquatic environment on sensor performance.

Development of Innovative Signal Processing: Exploitation of Geophysical Data Collected at the UXO Standardized Test Sites — The objective of this SON is to develop novel signal processing techniques applicable to the diverse detection and discrimination problems encountered on UXO-contaminated sites. Capabilities are needed in the interpretation of magnetic and electromagnetic data for a wide variety of site conditions, particularly those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. SERDP, ESTCP, and the U.S. Army's Environmental Quality Technology Program have sponsored the construction and operation of Standardized UXO Technology Demonstration Sites at Aberdeen Proving Ground, Maryland, and Yuma Proving Ground, Arizona, which have hosted more than two dozen sampling campaigns to collect digital geophysical data.

Innovative Technology for Detection, Discrimination, and Remediation of Unexploded Ordnance — The goal of this broad SON is to develop sensors, signal processing, platforms, systems, supporting technologies, phenomenology studies, or remediation technologies to address the diverse challenges associated with the cleanup of UXO-contaminated sites. Capabilities are needed for a wide variety of site conditions, including those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. Particular interest has been identified for (1) target reacquisition, (2) cluttered sites, (3) EMI operating parameters, and (4) recovery and disposal technologies for sites with limited access.

Significant Accomplishments

Hardware

SERDP-funded efforts in FY 2004 sought to improve the detection and classification of UXO through development of enhanced EMI sensor systems. Two teams from Lawrence Berkeley National Laboratory (LBNL) and the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) made significant progress in this area.

The LBNL team under the SERDP project **Detection and Classification of Buried Metallic Objects** developed an active electromagnetic (EM) system that can extract measurements for the best possible estimates of the location, size, shape, and metal content of a buried metallic object in the presence of an interfering response from the ground and/or non-UXO metallic objects. Since its initiation as an FY 2000 SEED effort, this project has sought to design an optimum system that provides the best detection of UXO with the lowest field survey cost. To achieve this goal, the project performed basic research to develop a systematic approach for the design and fabrication of an optimum active EM system based on the methodology employed in the minerals exploration industry to search for metallic ore bodies.

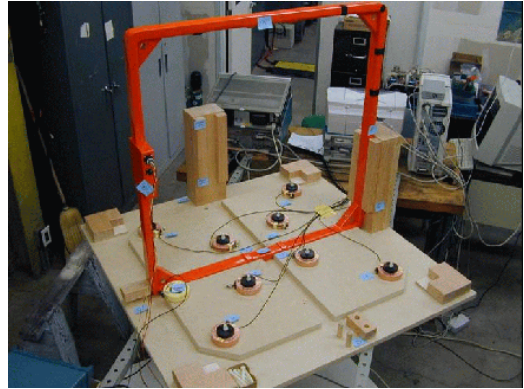


Figure II-9. Prototype Active EM System.

In FY 2004, the LBNL team completed a bench prototype EM system (see Figure II-9). This active EM system not only detects metallic objects but also is optimized to determine their size, shape, orientation, shell thickness, and metal content under real-world conditions. This prototype now provides promising UXO detection and discrimination capability, which will result in improved detection and substantially reduced field survey costs. The project has successfully transitioned the EM-based tools to ESTCP for full-scale demonstration and validation. This project was also recognized and awarded the FY 2004 SERDP UXO Project-of-the-Year Award at the *Partners in Environmental Technology Symposium & Workshop* held November 30 – December 2, 2004.

Signal Processing

For technologies used in characterizing sites contaminated with UXO, the most important metrics are high detection rates and low false alarm rates. Until recently, detection algorithms for processing sensor data could not effectively distinguish between buried UXO and non-UXO metallic clutter, even in the most benign conditions, leading to numerous false alarms. Recent advances have produced promising discrimination capabilities in favorable conditions. However, UXO is often found in densely



Figure II-10. Representative Samples of Ordnance, Scrap, and Other Metals.

contaminated areas where it is co-mingled with extensive surface and subsurface metal objects yielding overlapping signatures (Figure II-10). Over the last several years, modern geophysical techniques have merged sophisticated sensors, underlying physical models, and statistical signal-processing algorithms to approach these more difficult sites.

The goal of the SERDP project **Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites** is to improve signal-

processing approaches in highly contaminated regions with signatures of multiple anomalies that often overlap. To achieve this objective, a research team from Duke University is developing new physics-based signal-processing approaches that are applicable to commingled responses from UXO and clutter items in a sensor signal. In FY 2004, the research team assessed the performance of a number of simple prescreeners for detecting the presence of overlapping objects. The team is also investigating analysis techniques to correctly determine individual target properties when multiple objects are known to be present.

The objective of the SERDP-funded project **Physics-Based Modeling and Signal Processing for Synthetic Aperture Radar (SAR) Detection of Former Bombing Ranges and Burial Pits** is to study the utility of SAR for wide-area detection of UXO in the presence of naturally occurring clutter. Rigorous EM models and state-of-the-art signal processing tools are employed to investigate UXO detection in the presence of various soil types, surface conditions, and vegetation. The EM models are based largely on the state-of-the-art multilevel fast multipole algorithm (MLFMA), and the signal processing algorithms are based on hidden Markov models (HMM).

In FY 2004, the researchers developed a new theory based on Optimal Experiments that maximizes the information learned when targets are extracted based on the interpretation of geophysical data, such as the anomalies presented in Figure II-11. The research team is using the approach in collaboration with Sky Research, Inc. to perform wide-area assessment, determining from SAR and orthophotography data collected at the former Lowry Bombing Range whether a given region has been cleaned sufficiently. This new formulation should have a significant impact on near-range sensing (ground-based EMI/magnetometer, as already demonstrated) as well as for wide-area sensing, which is the focus of this SERDP project.

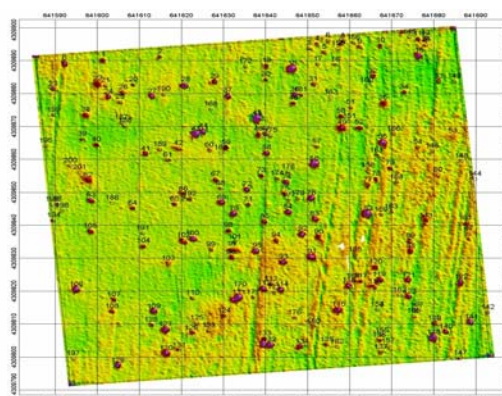


Figure II-11. Examples of Magnetic Anomalies Highlighted in a UXO Survey.

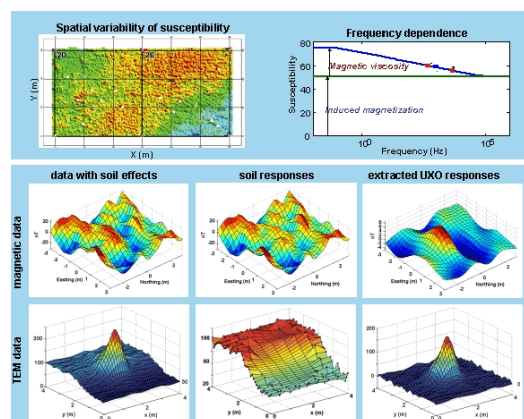


Figure II-12. Examples of Spatial Distribution and Frequency Dependence on Soil Susceptibility (top panels); Improvement in Sensor Data Can Be Obtained by Removing the Soil Effects (lower panels).

The SERDP project **Improving Detection and Discrimination of UXO in Magnetic Environments** focuses on practical questions regarding the physical understanding of magnetic soils, how to generate useful site characterizations of magnetic properties, and how to use information from the site characterization to process magnetic and EM data. In a precursor SERDP SEED project, this research team from the Colorado School of Mines completed modeling work showing the potential improvements in magnetic data using various data filtering techniques (Figure II-12). This work suggested that magnetometer and EM data could be made useful even for very stressing conditions with proper characterization and analysis. This SEED project transitioned to a full SERDP project in FY 2004 with initial tasks to characterize the magnetic environments at several UXO sites.

Through the SERDP SEED project **GEM-3D Sensor Development**, the U.S. Army Corps of Engineers ERDC constructed, debugged, and demonstrated at the bench and “backyard” level a new frequency domain (FD), ultra-wideband (UWB) EMI sensor configuration designated the GEM-3D. The driving force behind the design and development of this instrument is the need for improved UXO discrimination. To improve discrimination, a more complete EMI signature system for UXO and other metallic objects benefits from data processing that employs complete vector signal information.



Figure II-13. Three Receiver Coils on the EMI Sensor Head Measure Three Vector Components of Target Response Over Ultra-Wideband.

The configuration of the existing Geophex GEM-3 was used as a starting point for the new device. This modified approach completely defines the vector field that constitutes the EMI response of an object of interest (Figure II-13). The new sensor is handheld; therefore, it is capable of being swept and tilted in any direction, generating arbitrary angles of excitation and reception. The bench version of the instrument meets quantitative and qualitative performance objectives for discriminating UXO from metallic clutter.

ii. Chlorinated Solvents – Dense Non-Aqueous Phase Liquids

Scope of Problem

Chlorinated solvents are by far the most pervasive group of contaminants at DoD facilities. A recent estimate indicates that DoD owns more than 3,000 sites in the United States that are contaminated with chlorinated solvents. Chlorinated solvents exist as dense non-aqueous phase liquids (DNAPL) in the subsurface and serve as long-term sources of groundwater contamination. Historically, complete cleanup of these contaminant sources has been considered technically impracticable; therefore, the typical response action has been containment by pumping and treating the contaminated groundwater.

New technologies designed to remove the subsurface sources of DNAPLs have great promise to accelerate remediation. Examples include thermal treatment, chemical oxidation, bioremediation, and enhanced physical removal (e.g., using cosolvents or surfactants). Under appropriate conditions, these technologies can remove a large fraction of the total DNAPL mass. However, there is uncertainty regarding the benefits of using such technologies. Key questions for site managers include (1) Are the costs for source removal technologies justified in terms of the reduced need for, or duration of, active containment of the groundwater contaminant plume? (2) How much DNAPL source removal is required to cease active containment at a given site and to ensure protection of human health and the environment? and (3) Will contaminants migrate outside the treatment zone?

Overview of Investment

SERDP develops and promotes technologies to cost-effectively remediate chlorinated solvents in soil and groundwater. Technologies to detect and assess the presence and extent of both DNAPL source zones and dissolved plumes are essential. There is a need to understand the benefits of source zone treatment, particularly in-situ technologies. Further, by developing alternative solvents that are environmentally benign to replace chlorinated solvents and by developing new processes that do not require the use of chlorinated solvents, the DoD can eliminate the release of these materials to the environment. The following initiatives have been funded by SERDP to accomplish the Program’s objectives:

FY 2004 Completed Projects

- Aquifer Restoration by Enhanced Source Removal (CU-368), U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory
- In-Situ Clay Formation: A New Technology for Stable Containment Barriers (CU-1093), Sandia National Laboratories
- Aerobic and Anaerobic Transformation of cis-DCE and VC: Steps for Reliable Remediation (CU-1167), Michigan State University
- Characterization of the Aerobic Oxidation of cis-DCE and VC in Support of Bioremediation of Chloroethene-Contaminated Sites (CU-1168), Cornell University

FY 2005 Ongoing Projects

- Development of Effective Aerobic Co-Metabolic Systems for the In-Situ Transformation of Problematic Chlorinated Solvent Mixtures (CU-1127), Oregon State University
- Factors Affecting cis-DCE and VC Biological Transformation Under Anaerobic Conditions (CU-1169), Stanford University
- Foam Delivery of Hydrogen for Enhanced Aquifer Contacting and Anaerobic Bioremediation of Chlorinated Solvents (CU-1203), Rice University
- Development of Permeable Reactive Barriers Using Edible Oils (CU-1205), Solutions Industrial & Environmental Services, Inc.
- In-Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments (CU-1208), Rutgers University
- Improved Understanding of Fenton-Like Reactions for In Situ Remediation of Contaminated Groundwater Including Treatment of Sorbed Contaminants and Destruction of DNAPLs (CU-1288), Washington State University
- Improved Understanding of In Situ Chemical Oxidation (ISCO) (CU-1289), GeoSyntec Consultants, Inc.
- Reaction and Transport Processes Controlling In Situ Chemical Oxidation of DNAPLs (CU-1290), Colorado School of Mines
- Development of Assessment Tools for Evaluation of the Benefits of DNAPL Source Zone Treatment (CU-1293), Tufts University
- Mass Transfer from Entrapped DNAPL Sources Undergoing Remediation: Characterization Methods and Prediction Tools (CU-1294), Colorado School of Mines
- Impact of DNAPL Source Zone Treatment: Experimental and Modeling Assessment of Benefits of Partial Source Removal (CU-1295), U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory
- Using Advanced Analysis Approaches to Complete Long-Term Evaluations of Natural Attenuation Processes on the Remediation of Dissolved Chlorinated Solvent Contamination (CU-1348), Parsons Corporation
- Integrated Protocol for Assessment of Long-Term Sustainability of Monitored Natural Attenuation of Chlorinated Solvent Plumes (CU-1349), Virginia Tech
- Integration of Multi-Tension Permeametry and Photogrammetric Textural Segmentation for Estimating Directional Permeability (CU-1366), Pacific Northwest National Laboratory

- Hydraulic Tomography and High-Resolution Slug Testing to Determine Hydraulic Conductivity Distributions (CU-1367), University of Kansas
- Abiotic Reductive Dechlorination of Tetrachloroethylene and Trichloroethylene in Anaerobic Environments (CU-1368), University of Oklahoma
- Sustainability of Long-Term Abiotic Attenuation of Chlorinated Ethenes (CU-1369), University of Iowa

FY 2005 New Start Projects

- Oxygenase-Catalyzed Biodegradation of Emerging Water Contaminants: 1,4-Dioxane and N-Nitrosodimethylamine (CU-1417), University of California, Berkeley
- Investigation of Chemical Reactivity, Mass Recovery and Biological Activity During Thermal Treatment of DNAPL Source Zones (CU-1419), Georgia Institute of Technology
- Biodegradation of 1,4-Dioxane (CU-1422), Shaw Environmental & Infrastructure, Inc.
- Large-Scale Physical Models of Thermal Remediation of DNAPL Source Zones in Aquifers (CU-1423), TerraTherm, Inc.
- Prospects for Remediation of 1,2,3-Trichloropropane by Natural and Engineered Abiotic Degradation Reactions (CU-1457), Oregon Health & Science University
- In Situ Thermal Remediation of DNAPL Source Zones (CU-1458), Oregon Health & Science University

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released one SON addressing this issue.

Improved Understanding of the Distribution and Impacts of Subsurface Remedial Amendments in Groundwater — The objective of this SON is to develop an understanding of the migration and mixing of amendments injected in the subsurface to enhance the remediation of contaminated groundwater. Contaminants of greatest interest include chlorinated solvents, perchlorate, and munitions constituents. The research should lead to a better understanding of which site-specific factors control the delivery, mixing, and contact of amendments in the subsurface environment, as well as how to effectively monitor these factors to aid in the remedial design process.

Significant Accomplishments

In FY 2002, SERDP released two SONs to specifically address key issues involving DNAPLs. The first SON requested proposals to increase understanding of and develop characterization tools to assess the need for and impacts of DNAPL source zone treatment technologies. The second SON sought proposals to gain an improved understanding of the potential and limitations of in situ chemical oxidation (ISCO) for the destruction of DNAPLs. Three complementary projects were funded within each SON.

The DNAPL source zone and ISCO projects have each made great strides in FY 2004 toward answering some of the more difficult questions surrounding the remediation of DNAPLs. To encourage a high level of cooperation and coordination between principal investigators (PI) working on these efforts, SERDP formed two independent Technical Review Panels—one for the DNAPL Source Zone and one for ISCO. Biannually, the panel members provide suggestions and guidance to help facilitate the collaboration and sharing of information between these projects. The panels also help to identify gaps in DNAPL source zone and ISCO research and provide suggestions for the development of future SONs. The objective of the DNAPL Source Zone initiative is to make available to the user community a suite of tools for assessing the impacts of source zone treatment; the goal of the ISCO initiative is to develop a protocol

that can be used to guide future implementation of this technology in the field. Through collaboration and expert oversight, it is anticipated that progress in addressing the issue of chlorinated solvents will advance in a comprehensive and expeditious manner.

In Situ Chemical Oxidation

In the SERDP project **Improved Understanding of Fenton-Like Reactions for In Situ Remediation of Contaminated Groundwater Including Treatment of Sorbed Contaminants and Destruction of DNAPLs**, researchers from Washington State University are investigating the generation of transient oxygen species derived from the catalytic decomposition of hydrogen peroxide by soluble iron-catalyzed Fenton-like reactions. This work is increasing the fundamental understanding of the role of oxygen species in degrading common organic contaminants and the potential to treat contaminants in sorbed and DNAPL states. Results suggest that iron oxides play a significant role in hydrogen peroxide decomposition. Significant progress also has been made in completing studies of transient oxygen species generated with soluble iron that are capable of degrading DNAPLs.

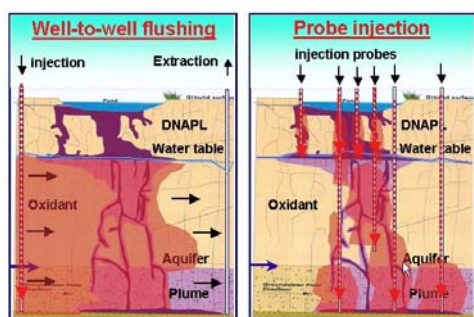


Figure II-14. In Situ Chemical Oxidation of DNAPL Sites Using Well-to-Well Flushing or Probe Injection Techniques.

Researchers at the Colorado School of Mines, under SERDP project **Reaction and Transport Processes Controlling In Situ Chemical Oxidation of DNAPLs**, are quantifying the reactions and transport processes that govern the delivery of oxidant to the DNAPL-water interface and the subsequent degradation of the DNAPL. This work is evaluating the chemistry of peroxide and permanganate oxidation and contrasting oxidant application methods (Figure II-14) to treat DNAPL under a range of subsurface settings. An experimental evaluation was conducted to couple ISCO with pre- and post-treatment operation of surfactant/cosolvent mass recovery and bioattenuation.

In the SERDP project **Improved Understanding of In Situ Chemical Oxidation**, researchers from GeoSyntec Consultants are developing a comprehensive understanding of the kinetics of contaminant oxidation by permanganate and Fenton's reagent. Research conducted in FY 2004 includes evaluating the effect of the aquifer matrix on oxidant mobility and evaluating the secondary impacts of ISCO on groundwater geochemistry and microbial activity at the field-scale (Figure II-15).

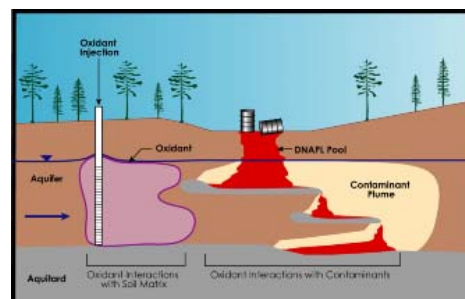


Figure II-15. Application of ISCO at the Field-Scale.

DNAPL Source Zone Treatment

In the SERDP project **Development of Assessment Tools for Evaluation of the Benefits of DNAPL Source Zone Treatment**, researchers from Tufts University, in partnership with the University of Michigan and the Georgia Institute of Technology, have worked to develop and evaluate a suite of tools that can be used by site managers to (1) predict and monitor contaminant plumes following DNAPL source zone treatment and (2) perform a cost/benefit analysis to select the best possible remedial technology. The team has developed a means to predict the DNAPL source longevity without treatment, with enhanced bioremediation alone, and with surfactant flushing followed by enhanced bioremediation. The results demonstrate the importance of understanding the distribution of the DNAPL in the subsurface

(Figure II-16). The team also has developed an uncertainty analysis model that evaluates the uncertainty in hydraulic conductivity and contaminant concentrations and can be used to determine how many samples are needed, where more sampling is needed, and how the uncertainty can be reduced most efficiently.

Researchers from the Colorado School of Mines, under the SERDP project **Mass Transfer from Entrapped DNAPL Sources Undergoing Remediation: Characterization Methods and Prediction Tools**, have been working to understand, quantify, and model the process of DNAPL contaminant mass transfer from source zones in heterogeneous aquifers where DNAPLs are undergoing physical, chemical, and biological transformation during remediation. Significant progress has been made on the development of models and on the use of partitioning tracers to estimate DNAPL contaminant mass. Results have shown that DNAPL partitioning behavior changes significantly as a result of biological or oxidation treatments, but not as a result of surfactant treatment. Preliminary analyses suggest that down-gradient DNAPL concentration and mass flux data can be used to effectively determine how best to capture and treat DNAPL source zones.

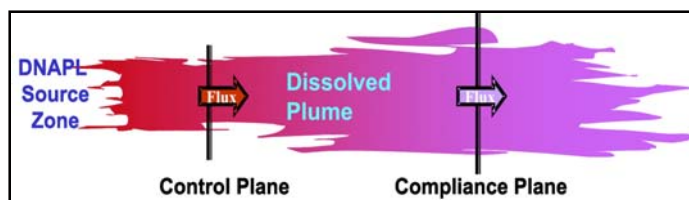


Figure II-17. Hypothetical DNAPL Source and Dissolved Plume.

fundamental premise behind this research is that contaminant flux from the DNAPL source should be used to evaluate the effectiveness of remediation (Figure II-17). Initial results show impressive reductions in mass flux at all sites, and the results will allow a comparison of different methods of measuring contaminant mass flux. Significant progress also has been made in developing an analytical model that predicts DNAPL source zone behavior with and without remediation and in linking this source zone model with transport equations to predict how the contaminant plume responds.

A separate, highly successful DNAPL remediation project funded by SERDP investigated the **Aerobic and Anaerobic Transformation of *cis*-DCE and VC: Steps for Reliable Remediation**. Researchers from the Georgia Institute of Technology evaluated the potential for bacteria to biodegrade the toxic compounds *cis*-1,2-dichloroethene (*cis*-DCE) and vinyl chloride (VC) under different redox conditions. Researchers identified metabolic reductive dechlorination ([de]chlororespiration) and aerobic energy-yielding oxidation as the dominant microbial processes involved in *cis*-DCE and VC detoxification. They also successfully isolated a previously unidentified bacterium—BAV1—that thrives on VC and, therefore, completely degrades the target contaminants to ethene, an environmentally benign product (Figure II-18). A site screening protocol was developed to

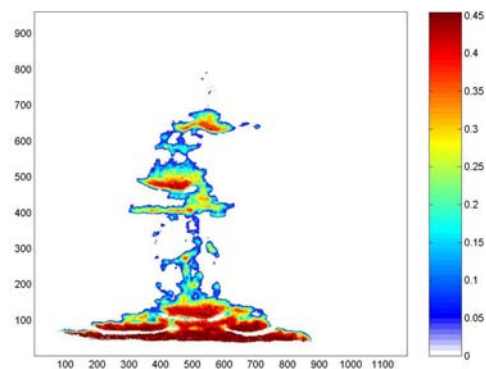


Figure II-16. Light Transmission Used to Characterize Initial DNAPL Source Zone Distribution.

In the SERDP project **Impacts of DNAPL Source Zone Treatment: Experimental and Modeling Assessment of Benefits of Partial Source Removal**, researchers from the EPA and the University of Florida are developing a scientifically defensible approach for assessing the long-term environmental impacts (i.e., benefits) of removing DNAPL source zones. The

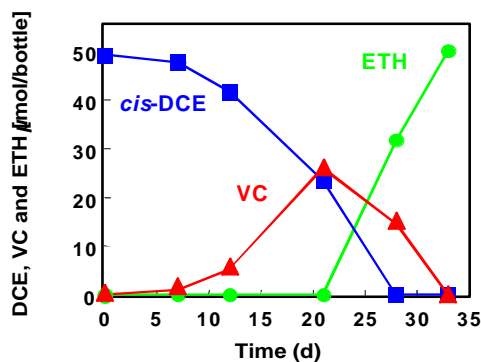


Figure II-18. Dechlorination of *cis*-DCE and VC by *Dehalococcoides* sp. Strain BAV1.

guide practitioners in evaluating site assessment data and in determining the most promising bioremediation approach. This project was recognized and awarded the FY 2004 SERDP Cleanup Project-of-the-Year Award at the *Partners in Environmental Technology Symposium & Workshop* held November 30 – December 2, 2004.

iii. Heavy Metals

Scope of Problem

Preventing the corrosion of metal components of military vehicles, aircraft, and weapon systems is a multibillion dollar challenge, accounting for 60% of annual DoD maintenance costs. Typically, corrosion is prevented by the application of sealants and coatings. Traditionally, chromium is used as the primary corrosion inhibiting substance for these sealants and coatings. Chromium has been designated as hazardous and needs to be eliminated from sealants and coatings to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. The DoD and DOE have committed to replace chromate-based sealants and metal finishing in current and next generation weapons systems. Strategic investments in chromate elimination research have been made, and these efforts have contributed significantly to our understanding of corrosion protection by chromates.

In addition, thousands of DoD sites require remediation as a result of contaminated soil. Heavy metals are among the most common soil contaminants, particularly cadmium, arsenic, chromium, and lead. DoD facilities can have extensive soil contamination, but complete removal is prohibitively expensive. One key aspect of the problem of heavy metals is how these contaminants affect living organisms. Over the past few years, SERDP has funded considerable research to identify environmentally acceptable levels and ecological screening levels of heavy metal contaminants in soil. Efforts also are underway to develop rapid, routine methods for measuring the bioavailability of heavy metals for plants and soil invertebrates.

Overview of Investment

Investments in the area of Heavy Metals span the Cleanup, Compliance, and Pollution Prevention thrust areas. SERDP develops and promotes techniques and technologies that cost effectively (1) evaluate the presence and disposition of heavy metals; (2) detect, monitor, and remediate hazardous metals and metal compounds in soil and groundwater; and (3) develop new materials and processes that eliminate the need for these metals. The detection and quantification of metals in soil continues to be an expensive and time-consuming laboratory process. Metals may be complexed or otherwise bound to materials in the soil matrix, and some of these binding methods are strong enough to resist acidic and enzymatic breakdown in plant and animal species. In these instances, not all metal contained in the soil is available for uptake (i.e., bioavailable). Regulatory limits often are set based on the total metal in the soil. This can result in cleanup limits that are overly conservative.

The development of environmentally benign alternatives to heavy metals that provide the same functionality and result in no loss in military performance is necessary. Until alternatives are developed for all applications, new technologies to recycle metal plating baths and control emissions and waste are needed. In addition, the recovery of heavy metals from weapon systems and platforms is required during demilitarization. The following initiatives have been funded by SERDP to accomplish the Program's objectives in this area:

FY 2004 Completed Projects

- Quantifying the Bioavailability of Toxic Metals in Soils (CU-1166), Oak Ridge National Laboratory

- Facilitated Immobilization of Heavy Metals in Soil by Manipulation with Plant Biproducts (CU-1352), University of Louisville
- Replacement of Non-Toxic Sealants for Standard Chromated Sealants (PP-1075), Air Force Research Laboratory
- Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection (PP-1119), Ohio State University
- Novel Conductive Polymers as Environmentally Compliant Coatings for Corrosion Protection (PP-1148), Naval Air Warfare Center
- Clean Dry-Coating Technology for ID Chrome Replacement (PP-1151), Naval Research Laboratory
- Electroactive Polymers as Environmentally Benign Coating Replacements for Cadmium Plating on High Strength Steels (PP-1411), Naval Air Warfare Center

FY 2005 Ongoing Projects

- Development of Extraction Tests for Determining the Bioavailability of Metals in Soil (CU-1165), Exponent, Inc.
- Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs (CU-1210), Ohio State University
- Decreasing Toxic Metal Bioavailability with Novel Soil Amendment Strategies (CU-1350), Oak Ridge National Laboratory
- Soil Amendments to Reduce Bioavailability of Metals in Soils: Experimental Studies and Spectroscopic Verification (CU-1351), Purdue University
- Anaerobic Biostimulation for the In Situ Precipitation and Long-Term Sequestration of Metal Sulfides (CU-1373), GeoSyntec Consultants, Inc.
- Environmental Fate and Exposure Assessment of Arsenic in Groundwater (CU-1374), California Institute of Technology
- Reduced Iron Sulfide Systems for Removal of Heavy Metals from Groundwater (CU-1375), University of Michigan
- Chromium-Free Application System for DoD Applications (PP-1341), University of Cincinnati
- Zeolite Conductive Polymer Coating System for Corrosion Control to Eliminate Hexavalent Chromium for DoD Applications (PP-1342), University of California, Riverside

FY 2005 New Start Projects

- Investigation of Chemically Vapor Deposited Aluminum as a Replacement Coating for Cadmium (PP-1405), Air Force Research Laboratory
- Electrolytic Plasma Processing for Sequential Cleaning and Coating Deposition for Cadmium Plating Replacement (PP-1406), Naval Research Laboratory
- Development of Chrome-Free Welding Consumables for Stainless Steels (PP-1415; this is follow-on work related to SEED Project PP-1346), Ohio State University
- Investigation of Chemically Vapor Deposited Tantalum for Medium Caliber Gun Barrel Protection (PP-1425), New Jersey Institute of Technology
- Chromium Elimination in Medium Caliber Gun Barrels (PP-1426), U.S. Army Benet Laboratories

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released one SON addressing this need.

Environmentally Benign Finishing/Coating Systems for DoD Substrates — The objective of this SON is to develop chromate-free, zero volatile organic compound (VOC), zero hazardous air pollutant (HAP), and zero TRI chemical finishing and coating systems for a variety of DoD substrates including aluminum alloys, steels, and composites. An environmentally benign finishing system would greatly reduce the amount of VOCs, HAPs, and heavy metal emissions emitted during painting and depainting operations. It also would reduce the costs and logistical burdens associated with the handling and disposal of hazardous wastes that result from these operations.

Significant Accomplishments

Fate and Transport

Beyond the DoD industrial complex, antifouling coatings on ship hulls represent one of the largest contributors of the heavy metals, copper (Cu) and zinc, loading to harbors and estuaries. The predominate type of antifouling paints used by the DoD today is the ablative copper coating which is approximately 40-45% copper and 20% zinc. Other potentially toxic sources of these metals include industrial and non-point source effluent such as storm water and disrupted sediments. Regulatory compliance is often challenging in DoD harbors because of the many sources of copper and the adoption of very conservative water quality standards. Copper and zinc discharges often exceed existing water quality criteria (WQC) or standards in effluent and receiving systems, which are based on total copper concentrations. However, a large body of scientific data indicates that the concentration of free aqueous Cu^{2+} ion ($[\text{Cu(II)aq}]$), rather than total copper concentration, relates most closely to the toxicity of marine organisms. The availability of free aqueous Cu^{2+} ion is being shown to be regulated by the copper complexation capacity of organic ligands. These ligands, which are usually present in aquatic environments in excess of the total copper concentration, accept a certain amount of total copper before the onset of toxic effects. Therefore, both free copper ions and copper complexation capacity are parameters related to the health and ability of an aquatic system to endure copper inputs.

The SERDP project **Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program** evaluated the sources of copper and provided critical input parameters to model the distribution of copper in Navy harbors. Field efforts conducted by researchers from the Space and Naval Warfare Systems Center successfully established baseline water quality conditions and copper concentrations and identified the locations and extent of copper and zinc throughout San Diego Bay in California. The distribution of copper complexation capacity in San Diego Bay indicates that the bioavailable fraction of copper is maintained below toxic levels in ambient waters of the bay. The data represents one of the most comprehensive spatial and temporal descriptions of copper and zinc in a harbor system and provide a basis for future assessment of new regulatory tools such as the Biotic Ligand Model (BLM). BLM analyses of the effect of site-specific water characteristics on copper bioavailability and toxicity indicate that the national WQC for copper are overly conservative in San Diego Bay and that a site-specific copper standard would be more representative of actual conditions in this receiving system. The models implemented by this SERDP project are undergoing further demonstration and validation under the auspices of ESTCP through a collaborative effort of EPA, HydroQual, and various DoD test sites.

Bioavailability

Under the SERDP project **Quantifying the Bioavailability of Toxic Metals in Soils**, researchers from Oak Ridge National Laboratory and Auburn University investigated the relative bioavailability of toxic metals (i.e., lead, zinc, copper, cadmium, arsenic, chromium, and nickel) in soils, in relation to the human health risk posed by soil ingestion (Figure II-19). Researchers found that the bioavailability of these metals is based on generic soil-metal interactions rather than metal-specific speciation. The bioavailability of arsenic in soils depends mainly on the soil's pH and iron oxide content, while the bioavailability of chromium in soils depends mainly on total carbon (both organic and inorganic) and clay content. Models developed under this project were used to predict both arsenic and chromium bioavailability based on these major soil properties.

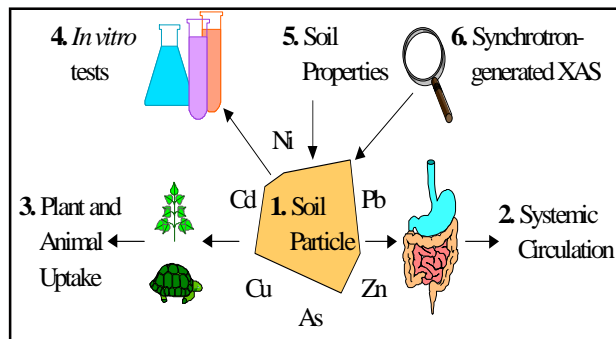


Figure II-19. Metals in Soils (1) Pose a Human Health Risk via Soil Ingestions (2) and an Ecological Risk via Plant and Animal Uptake (3). Models to Predict In Vitro Measured (4) Bioavailability Based on Soil Properties (5) Using X-Ray Absorption Spectroscopy (6) Provide a Fundamental Understanding of Metal Bioavailability.

The SERDP project **Development of Extraction Tests for Determining the Bioavailability of Metals in Soil** is developing a suite of simple and easy-to-use extraction tests to predict human and ecological exposures to metals in soil. Such tests will provide inexpensive and rapid tools for establishing the bioavailability of metals in soils at DoD sites. Researchers from Exponent, Inc. completed an evaluation of which metals most often occur as contaminants and drive remediation activities at DoD sites. Overall, the project's results provide a fundamental understanding of the bioavailability of several metal species in soils and how various soil properties may affect metals bioavailability and the accuracy of the measured bioavailability estimates.

Results from these two projects provide site managers and risk assessors with effective tools to make better estimates of site risk resulting from heavy metal contamination. The models developed at Auburn University can be used to prioritize high-risk sites and to justify more definitive site-specific bioavailability studies used in final cleanup decisions, following the protocols developed by Exponent, Inc. and demonstrated by others in the field.

Pollution Prevention

The welding of stainless steel metal parts is an integral process used throughout the DoD. Virtually all the Services, from the Navy Depots and Shipyards, the Air Force Air Logistic Centers, to the Army Arsenal facilities, conduct welding on a daily basis. As much as 200 pounds per year of hazardous chromium (Cr) fumes are generated at a single site from welding repairs. To address this issue, the SERDP SEED project **Novel Approach for Welding Stainless Steel Using Cr-Free Welding Rods** developed a Cr-free consumable for welding austenitic stainless steel that provides mechanical properties and corrosion resistance comparable to the Cr-bearing consumable that is currently used. Researchers from Ohio State University found that type 304L stainless steel can be welded with Monel filler metal to create high quality welds with no cracks. The welds pass bend tests and can survive long-term exposure to mildly aggressive environments with no evidence of corrosion. This project provided a proof-of-concept for the novel approach to welding of stainless steel, and a follow-on project **Development of Chrome-Free Welding Consumables for Stainless Steels** has been initiated to complete the welding rod alloy development and prove its suitability for adoption in the field.

The DoD expends significant resources every year to implement corrosion protection strategies for its assets. Most of these corrosion protection practices are based on the use of barrier coatings and paints that contain chromates. Currently, chromate-free conversion coatings do not match the level of corrosion protection provided by chromate conversion coatings. To a large extent, coating formulators do not know what attributes of chromate coatings result in their superior performance. To understand this issue, SERDP funded the **Critical Factors for the Transition from Chromate to Chromate-Free Corrosion Protection** project to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection provided by chromate-based coatings applied to metal surfaces, with an emphasis on aluminum alloys. This project is a four-year fundamental research effort conducted jointly by Ohio State University, the Air Force Research Laboratory, and the Army Research Laboratories. This increased understanding of the conversion coating process will lead to the development of alternative nonchromated coatings that meet or exceed the performance specifications of existing coatings.

iv. Air Emissions

Scope of Problem

Air emissions are generated from many sources on military installations. The painting and depainting of military equipment generates large quantities of air emissions. Weapon system platforms such as ships, airplanes, and ground vehicles also are a source of air emissions as system performance was the main criteria for their development and air emissions were not a major design consideration. The 1990 Clean Air Act Amendments (CAAA), the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission of air pollutants such as VOCs. The production of ozone depleting substances (ODS) has been banned under national policy and international (Montreal) protocol. Federal and state environmental agencies have been authorized to regulate PM and polycyclic aromatic hydrocarbons (PAH) emitted from local sources. Military bases increasingly are being identified as point sources of these pollutants and being held accountable for their emissions.

DoD directives require significant reductions in hazardous air emissions and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of air emissions that are expensive to treat or control. The Services as well as SERDP are addressing the upcoming 10-year Surface Coating National Emission Standards for Hazardous Air Pollutants (NESHAP) through research and development to develop technologies to reduce or eliminate air emissions.

Overview of Investment

SERDP develops and promotes technologies and/or materials that eliminate, reduce, or control environmentally damaging VOCs, HAPs, particulates, and ODSs from DoD platforms, weapons systems, and industrial processes. There is a need for technologies to rapidly detect and classify these compounds, and control of these releases is required. Environmentally benign alternatives include new materials to replace these compounds, new processes that eliminate the use of these compounds, and new processes that reduce or eliminate the production of these compounds as a by product. The following initiatives have been funded by SERDP to accomplish the Program's objectives:

FY 2004 Completed Projects

- Electrostatic Fuel Atomization for Gas Turbines to Achieve Reductions in Particulate Emissions (PP-1184), U.S. Army Benet Laboratories
- Low Temperature Powder Coatings (PP-1268), GE Global Research Center

FY 2005 Ongoing Projects

- Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives (PP-1179), Air Force Research Laboratory
- A NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception During Combustion (PP-1198), National Institute of Standards and Technology

FY 2005 New Start Projects

- Tropodegradability and Micellization: New Approaches to Achieving Ozone-Safe Solvents (PP-1407), National Institute of Standards and Technology

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released two SONs to address these issues.

Environmentally Benign Finishing/Coating Systems for DoD Substrates — This SON solicits proposals to eliminate the use of heavy metals in finishing and coatings processes. The objective of this SON is to develop chromate-free, zero volatile organic compound, zero hazardous air pollutant, and zero TRI chemical finishing and coating systems for a variety of DoD substrates including aluminum alloys, steels, and composites. An environmentally benign finishing system would greatly reduce the amount of VOCs, HAPs, and heavy metal emissions emitted during painting and depainting operations. It also would reduce the logistical burdens associated with the handling and disposal of hazardous waste generated by these processes.

Development of Miniaturized Sensors to Monitor or Determine Environmental Parameters — This SEED SON seeks proposals to develop miniature sensors for monitoring one or more of the following environmental parameters: water quality, waterborne pollutants, and air quality. Miniature instrumentation through the use of micro- and nano-electronics and biochemical process regulation have come to the forefront in their use to monitor various biological and chemical processes in the environmental sciences. Air monitoring devices for nitrogen oxides, sulfur oxides, ozone, and particulates are required to keep track of volatile materials used in a wide variety of remanufacturing and repair activities undertaken by the DoD in the maintenance of its weaponry and support equipment.

Significant Accomplishments

The DoD currently spends millions of dollars each year to procure, use, and dispose of toxic and hazardous materials associated with solvent-borne organic coatings. Powder coatings have the potential to eliminate more than 95% of the toxic and hazardous materials used in the production and application of current corrosion-protection coatings. Numerous aircraft parts, weapon systems, and support equipment require corrosion coatings but are made from temperature-sensitive materials such as low-tempered aluminum.



Figure II-20. Low-Temperature Powder Coating on Navy Support Vehicles.

To address this problem, SERDP funded a research project entitled **Low-Temperature Powder Coating** to develop an exterior-use, corrosion-protection powder coating that cures at a temperature of 120°C within 30 minutes. This technology was tailored for military ground support equipment constructed from temperature sensitive aluminum (Figure II-20). The coating has been shown to simultaneously meet all screening performance criteria including impact toughness, hardness, salt-fog and sulfur dioxide corrosion resistance, surface quality, and exterior durability. These powder coatings are inherently free from

VOCs, chromates, and HAPs. Relative to the existing solvent-borne urethane paint system, the powder coating eliminates the need for a chromated primer and has the potential to increase application efficiencies by 35%, while reducing raw material and paint facility operating costs. The project, led by GE Global Research Center, was recognized and awarded SERDP's Pollution Prevention 2004 Project-of-the-Year Award at the *Partners in Environmental Technology Symposium & Workshop* held November 30 – December 2, 2004.

The military and their engine manufacturers have been working to reduce PM and PAH formation in existing and future engines. To meet this challenge, SERDP initiated the project **NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception during Combustion** to study soot formation to develop a database describing the transformation of fuel molecules to their desired end products of carbon dioxide and water, as well as to the undesired PAH, and to develop the first quantitative soot particle inception model. Researchers also developed a well-stirred reactor (Figure II-21) to collect the first data on the effect of equivalence ratio on soot particle size. This improved understanding of soot particle formation will lead to the development of cleaner burning engines for use by the DoD.

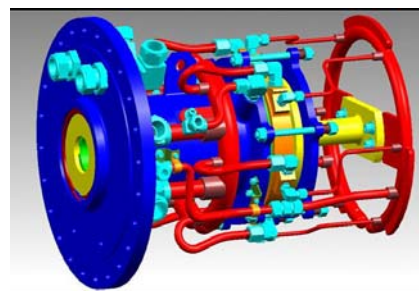


Figure II-21. Illustration of Air Force Research Laboratory High-Pressure, Well-Stirred Reactor.

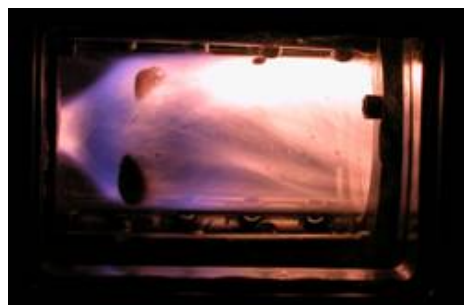


Figure II-22. High-Pressure Turbulent Combustion Reactor Used to Evaluate and Reduce PM Formation.

It is estimated that U.S. military aircraft emit approximately 600,000 kilograms of PM into the atmosphere each year. Most of this particulate matter is in the form of soot particles with diameters of less than 2.5 microns. To address this concern, SERDP sponsored the **Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives** project to identify and develop one or more additives for JP-8, JP-5, and diesel fuels that will reduce both the mass Emissions Index and the number density Emissions Index of PM_{2.5} at the exhaust exit of military gas turbine engines by 70%. Using a high-pressure turbulent combustion reactor, research by the Air Force Research Laboratory has indicated that the mechanism by which soot is reduced by the nitro-alkanes is more complex than preliminary hypotheses (Figure II-22). Modeling work has begun to explore more fully the mechanism using a chemical kinetic mechanism created by the National Institute of Standards and Technology team that is also funded by SERDP.

v. Hazardous Materials/Solid Waste

Scope of Problem

The majority of DoD maintenance and repair activities for weapon system components involve the use of toxic or hazardous substances. Occasionally, these materials become waste products and make their way into the soil, sediments, air, or groundwater. From the deicing of aircraft and runways to removing coatings from substrates, hazardous substances are a DoD-wide problem. In addition to hazardous wastes, DoD must contend with the problem of nonhazardous solid waste. This waste includes the packaging materials needed to sustain personnel both at home and deployed in the field. The areas of hazardous and nonhazardous solid waste are a large environmental problem that DoD must try to resolve.

Overview of Investment

SERDP develops and promotes techniques and technologies that cost-effectively eliminate, reduce, or control hazardous materials in soil, sediments, air, and groundwater. The elimination of hazardous materials from military platforms and weapons systems is the preferable solution. The guiding principle is that there will be no net loss of military capability with the alternative material. In cases where environmentally benign alternatives have not been identified, control technologies, coupled with recycling and reuse methods, as well as remedial technologies need to be developed. The following initiatives have been funded by SERDP to accomplish the Program's objectives in the area of Hazardous Materials/Solid Waste:

FY 2005 Ongoing Projects

- Next Generation Fire Suppression Technology Program (PP-1059), National Institute of Standards and Technology
- Reduction of Solid Waste Associated with Military Rations and Packaging (PP-1270), U.S. Army Natick Soldier Center
- Low-Cost and High-Impact Environmental Solutions for Military Composite Structures (PP-1271), U.S. Army Research Laboratory
- Characterization of Contaminant Migration Potential Through In-Place Sediment Caps (CU-1370), Battelle Memorial Institute
- Integrating Uncertainty Analysis in the Risk Characterization of In-Place Remedial Strategies for Contaminated Sediments (CU-1371), University of Michigan

FY 2005 New Start Projects

- Non-Leaching, Benign Antifouling Multilayer Polymer Coatings for Marine Applications (PP-1454), Cornell University
- Heavy Metal Ion Sensors Combining Catalytic DNA in a Nonfluidic Intelligent Processor (CP-1459), U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory

FY 2006 Initiatives

In the FY 2006 solicitation, SERDP released six SONs in the area of Hazardous Materials/Solid Waste that encompass sediments, green synthesis routes, solid packing waste, and deicing fluids.

Assessment and Measurement of Processes Impacting the Fate and Transport of Contaminants in Sediments — This SON seeks proposals that address the following high priority needs: (1) site characterization tools to measure the rates of important sediment chemical/physical/biological processes affecting the fate and transport of contaminants; (2) tools and techniques to assess site-specific bioavailability and bioaccumulation of contaminants at sites; (3) improved understanding of how sediment geochemical composition influences contaminant partitioning and bioavailability; (4) understand and quantify sediment exchange processes with overlying water and groundwater; and (5) improved methods for incorporating uncertainty into measurements of fundamental fate and transport processes.

Development and Placement of Amendments for In Situ Remediation of Contaminated Sediments — This SON solicits for the development of new amendments as well as an improved scientific understanding of their mechanisms, both in active caps and as in situ treatment. Associated with the development of these amendments is the critical issue of placement, distribution, and stability and how

design of caps will be influenced by the choice of reactive material. A greater understanding of the physical, chemical, and microbial processes involved in the fate, transport, degradation, and sequestration of contaminants in sediments will facilitate the establishment of more cost-effective and efficient remedial action plans that are protective of human health and the environment.

Environmentally Benign Synthesis of Energetic Compounds and Their Precursors — The objective of this SON is to develop innovative environmentally responsible techniques to produce MC and their precursor materials for DoD applications. Currently, MCs are produced using classical nitration/nitrolysis chemical reactions that often employ harsh and nonselective reaction conditions. Use of green chemistry processes could result in a substantially smaller waste stream as well as higher product yields and energy savings.

Reduction/Elimination of Non-Hazardous, Solid Packaging Waste — The objective of this SON is to develop innovative materials and/or techniques to reduce the quantity of nonhazardous solid packaging waste associated with deployed forces. The DoD is having difficulty managing nonhazardous solid waste that is generated from overseas base camps. Beyond environmental problems created by large quantities of solid waste, operational issues arise when personnel and equipment are focused on the management and transport of waste rather than the achievement of operational objectives.

Environmentally Benign Runway Deicing — This SON solicits for the development of environmentally benign technologies and approaches for deicing airport runways. When civilian and military runways become coated with frozen precipitation, they must be cleared to ensure effective, safe operations at the facility through use of chemical deicers. This SON seeks runway deicers that are not only environmentally benign, but also will not corrode or damage metal and nonmetal aircraft and support equipment components.

Development of Miniaturized Sensors to Monitor or Determine Environmental Parameters — This SEED SON seeks proposals to develop miniature sensors for monitoring one or more of the following environmental parameters: water quality, waterborne pollutants, and air quality. Monitoring devices for dissolved oxygen and turbidity as well as metals, PAHs, and polychlorinated biphenyls will help to assess activities undertaken by the DoD in aquatic environments.

Significant Accomplishments

To sustain deployed personnel stationed in vastly diverse climates and situations, DoD must provide food that can be stored for long periods of time without spoiling. These meal-ready-to-eat (MRE) items must have a shelf life of three years at 80°F, six months at 100°F, and must be able to withstand being dropped from an airplane to troops in forward or remote regions. MREs must be packaged in such a way that the food inside is not damaged or spoiled by extreme heat or rough treatment. Currently, MREs are packaged with multilayer materials and use foil as a barrier. Approximately 46.6 million MREs are consumed each year, which leads to 14,117 tons of packaging waste.

The SERDP Project entitled **Reduction of Solid Waste Associated with Military Rations and Packaging** is developing a biodegradable nanocomposite-based packaging material that will eliminate the need for a foil barrier in DoD MREs. The new material is biodegradable, and the absence of foil further reduces the amount of solid waste resulting from the consumption of MREs. Several

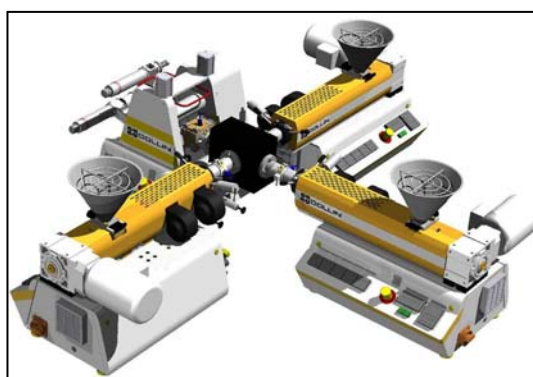


Figure II-23. Collin Teach-Line Multilayer Extrusion System Used to Produce a Five-Layer Biodegradable Packaging Film from Three Different Materials.

formulations of packaging films have been optimized on pilot-scale equipment by the U.S. Army Natick Soldier Center (Figure II-23). These pilot scale tests have produced films that have similar barrier, thermal, and mechanical properties to the materials that are currently used in MREs. These new packaging materials will yield a complete suite of MRE packaging materials that are either biodegradable or recyclable. Implementation of composting and recycling will reduce the MRE waste stream to only the heating elements contained within.

Recently, the EPA increased legislation to address hazardous emissions from composite manufacturing and repair by enacting new emission standards through the Reinforced Plastic Composites Production NESHAP, which specifically targets styrene, methyl methacrylate, and methylene chloride as regulated HAP. VOCs are emitted during all phases of composite fabrication. The SERDP project entitled **Low-Cost and High-Impact Environmental Solutions for Military Composite Structures** led by the Army Research Laboratory was initiated to research, develop, and demonstrate low VOC emission, high performance vinyl ester (VE) resins to comply with the new EPA regulations. The project seeks to reformulate resin compositions used in liquid molding fabrication to decrease VOC concentrations, resulting in reduced emissions throughout the composite life cycle. Overall, the project has been successful in identifying critical DoD environmental needs, developing practical solutions to these requirements, and developing candidate resins for reducing VOC emissions from VE resins for military applications. Additional work is required to further optimize these candidate resins.

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III. MANAGEMENT ACTIONS

A. Council Actions

Multiagency management and oversight of SERDP continues to be one of the clear strengths of the Program. Active participation by the members of the SERDP Council, their designated representatives on the EWG, and the TTAWG precludes duplication of effort, ensures quality Program content, and facilitates information transfer. This tripartite arrangement, composed of executive, programmatic, and technical individuals who represent the three primary participating organizations, yields a depth and breadth of knowledge and experience at several levels of management and technical expertise that lend significant credibility to the Program.

On September 30, 2003, the SERDP Council approved the FY 2004 Program Plan and the FY 2005 Investment Plan. For FY 2004, SERDP was appropriated \$50.618 million, which included funding for two congressional interest projects.

Multiagency participation is a clear strength of the Program.

The Council met one year later on September 29, 2004 to approve the FY 2005 Program. The President's Budget Request for SERDP for FY 2005 represented an increase of \$6.3 million from the FY 2004 appropriation. The congressional appropriation for FY 2005 increased SERDP's budget to \$57.9 million, which included one congressional interest project. The Council approved the FY 2005 Core program as presented. The Council further granted the Executive Director the authority to execute any congressional interest projects that may be added to the appropriation to ensure that they are appropriately focused on defense issues. The Council also reviewed and approved the FY 2006 investment guidance.

B. Executive Director and Program Office

The SERDP Executive Director, Technical Director, and Program Office staff continued to ensure that the Program focuses on the mission needs of the DoD via refining and implementing an investment strategy that successfully satisfies these mission needs. In FY 2004, the Executive Director and Program Office staff continued the Program's emphasis on (1) research to support the sustainability of range operations and the reduction of current and future liabilities; (2) solicitation and selection of proposals from the broadest possible pool of world class researchers; and (3) promotion of technology transfer to ensure the rapid transition of innovative technologies to the DoD user community.

i. Continued Emphasis on Unexploded Ordnance and Range Sustainability

In FY 2005, the cost to cleanup UXO at sites other than operational ranges is estimated to be \$27 billion. SERDP's belief is that the development of advanced technology can reduce this cost by nearly 70%. SERDP continued to coordinate its UXO research efforts with the DoD's Joint UXO Center of Excellence and remain abreast of new initiatives developed with the Counter Mine efforts, such as found within the Multiple University Research Initiative (MURI). Furthermore, the UXO Program plan undergoes a thorough peer review every year to ensure that it properly characterizes the broad problem, establishes clear and logical goals, and identifies specific, relevant, near-term technical objectives.

SERDP continued to refine its investment strategy that frames research topic areas in terms of DoD priorities. The strategy is based on the premise that the Department's environmental issues fall into two major areas. The first area is **Sustainability of Ranges and Range Operations**, which includes maritime

sustainability, TES, active clearance of unexploded ordnance, toxic air emissions and dust, urban growth and encroachment, and noise. The second area of the SERDP investment strategy is **Reduction of Current and Future Liability**, which addresses (1) contamination from past practices and includes research on intractable chlorinated solvents, UXO cleanup, and emerging contaminants such as perchlorate and (2) pollution prevention to control life-cycle costs, which includes elimination of hazardous materials to reduce the cost of operation, repair, and demilitarization as well as achieving compliance through Pollution Prevention. The shift of SERDP investment to UXO detection and discrimination as well as the emphasis on range sustainability research across thrust areas over the past several years reflects SERDP's focus on priority investment opportunities.

ii. Proposal Solicitation and Selection

SERDP takes pride in the fact that funds for new start projects are available to industry, academic, and federal researchers alike, and the SERDP Council continues to be pleased with SERDP's ability to reach out to a broader pool of researchers through a Broad Agency Announcement (BAA). SERDP again extended two solicitations – a “Core” solicitation that has traditionally been used to develop the annual program and a SEED solicitation. The SEED Program is designed to provide initial funding for high-risk, high-payoff proof-of-concept projects. Funding is limited to a maximum of \$100,000 for up to one year. Successful efforts may compete for additional funds in the following years.

iii. Technology Transfer

Since 1991, SERDP has funded more than 500 individual projects. Several avenues are taken to ensure that the successful efforts of the research teams are transitioned to either higher development programs, such as ESTCP, or implemented directly into field use.

Technology transfer and transition continued to be a primary area of focus during annual project reviews by both the SERDP SAB and the TTAAGs. Principal investigators were tasked to prepare Annual Technical Reports that serve as a fundamental baseline of technical progress. At the end of each project, a Final Technical Report is required. These reports are maintained in an online library maintained by SERDP and ESTCP. Additionally, they are entered into the Defense Technical Information Center (DTIC) in both a hard copy and electronic version. DTIC provides all researchers with copies of these reports upon request.

SERDP has posted Fact Sheets on its web site for every SERDP funded project, past and present. These Fact Sheets include summaries of the technical accomplishments and potential benefits of each project. The SERDP web site also provides links to web sites maintained by SERDP researchers that give additional information about technologies developed under SERDP.

Each year, SERDP, in cooperation with ESTCP, hosts the *Partners in Environmental Technology Technical Symposium & Workshop*. This event has, for the past nine years, attracted hundreds of researchers, technology developers and users, and regulators to meet in a collegial and informative setting. In December 2004, the annual Symposium once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the federal laboratory system and the nonfederal sector alike. Our venue focused on “Meeting DoD's Environmental Challenges Sustaining Our Ranges; Reducing Environmental Liabilities” in recognition of the fact that, while significant advances have been made in addressing environmental issues, additional challenges continue. This event brought nearly 800 technology developers and implementers together, as well representatives from the policy, programmatic, regulatory, academic, and industrial sectors. The annual SERDP Project-of-the-Year Awards were given to the best projects in each of the five Thrust Areas for FY 2004. These awards have successfully attracted the attention of the scientific and engineering community around the globe and have measurably helped either to transition this technology into higher

development programs or to implement its use in field applications. This conference, which has received numerous accolades, will continue to be enhanced to serve as a significant technical, educational, and technology transfer event.

C. Actions of the SERDP Scientific Advisory Board

In accordance with Section 2904, Title 10, U.S.C., the SERDP SAB is required to meet a minimum of four times during the fiscal year. In FY 2004, the SAB met four times. Consistent with the statute, the Board made recommendations to the SERDP Council through the Executive Director regarding the projects reviewed. They also assisted and advised the Council in identifying environmental opportunities and provided advice on other environmental issues within the scope of SERDP.

Figure III-1 provides a list of dates and locations of all SAB meetings held during FY 2004. In accordance with the Federal Advisory Committee Act, all meetings were open to the public and detailed records of events are maintained. Further, all records, reports, working papers, and agendas were made available to the public for review. In FY 2004, no requests were made to review this information.

SAB Meeting Number	Date	Location	Projects Briefed		
			New Start	Continuing	Total
1	October 1-3, 2003	Arlington, VA	7	6	13
2	March 31-April 1, 2004	San Diego, CA	13	1	14
3	June 9-10, 2004	Arlington, VA	3	3	6
4	September 8-9, 2004	Arlington, VA	15	-	15

Figure III-1. Summary of FY 2004 SAB Meetings.

The Board continued its proactive strategic role in identifying and defining environmental research gaps and associated technology development opportunities. The Board continued to support strongly the concept of focused technical workshops to provide an assessment of the state of the science and identify and prioritize specific research needs in areas of interest to SERDP. Several Board members actively participated in these workshops. As a result of these workshops, numerous SONs were generated.

During their review and evaluation of proposals, the SAB conscientiously scrutinized each effort to understand and enhance the research partnerships that were proposed. Considered to be a major strength of the Program, cooperative research efforts have demonstrated a higher quality of effort by ensuring that each facet of the project is afforded a second look and chance to ensure that it is conducted with the highest standards. Where appropriate, the SAB suggested improvements or additions to the research team – from inclusion of a Co-PI having specific disciplinary credentials that would enhance the research effort to offering suggestions of organizations that might shed additional light and enhance the standards and procedures proposed in the effort. The SAB also strongly encouraged inclusion of graduate students in research teams to promote training and foster development of technical expertise in cutting-edge technologies.

The Board continued its key focus on assisting SERDP to ensure that SERDP-supported projects meet the highest standard of technical and scientific quality. The SAB addressed this issue from three avenues.

- First, the SAB firmly supports SERDP's procedure to have each and every proposal reviewed by at least three Peer Reviewers who are experts in the discipline most closely related to the proposal's technical approach.
- Second, the members encouraged close coordination between projects that address related problems.

- Third, the Board fully supported the midyear In-Progress Review of each project by the TTAWGs.

The SAB continued to emphasize technology transfer potential as an important criterion for evaluating proposals. Technology transfer is one of the SERDP Keys to Success, and the Board members continued their keen interest in the role of the military Services and eventual users of the technologies being developed. Complete technical reporting, including publications in the peer-reviewed literature as well as SERDP-required interim and final technical reports, was a metric used to determine project technical achievement and management acumen.

The SAB continued its participation in the planning and execution of the annual *Partners in Environmental Technology Technical Symposium & Workshop* sponsored by SERDP. During strategy discussions at SAB meetings, the members offered comments on the overall theme of the Symposium and suggestions for technical session topics and plenary and session speakers. SAB members continued the tradition of active involvement in the planning of technical breakout sessions. The active involvement of the SAB has been a significant contributing factor to the overall success of each Symposium.

In the past the SAB has suggested areas of opportunity for SERDP investment. Often, these areas prove to become the focus of a national or worldwide research effort. An example of research that commenced at the suggestion of the Board is the remediation of groundwater contaminated with perchlorate. Due to their proactive thinking, SERDP was able to get a head start on understanding this phenomenon and initiating research to resolve associated issues.

Consistent with past practice, the Executive Director solicited the advice of the membership regarding his proposed allocation of funds among the five Thrust Areas for FY 2004. The Board was fully supportive of the proposed profile and general trends of investment within each of the five Thrust Areas. A summary of all projects reviewed by the SAB and the results of their deliberations may be found in Figure III-2.

At the September 2004 SERDP Council meeting, Dr. C. Herbert Ward, Chair of the SAB advised the Council of how the SAB ensures that quality research is focused on high-priority DoD needs and that technology transfer is fostered to the users in the field. Dr. Ward was supportive of the Program stating that during his tenure, SERDP has become increasingly more rigorous in funding higher quality research overall. He opined that SERDP research on state-of-the-art technologies is well published and is recognized worldwide. He noted that the process for appointing SAB members was inefficient and resulted in the late appointments of many members.

Project Number	Recommendation				FY04 Meeting Date				New Starts	Continuing Projects
	Fund		Not Fund		1	2	3	4		
	FY04	FY05	FY04	FY05	Oct-03	Mar-04	Jun-04	Sep-		
CP-1305	\$284				Oct-03					•
CP-1336	\$922				Oct-03					•
CP-1410 ⁽²⁾	\$100					Mar-04			•	
CP-1399 ⁽³⁾	\$554					Mar-04			•	
CP-1400 ⁽³⁾	\$554					Mar-04			•	
CP-1155		\$1,238					Jun-04			•
CP-819 ⁽¹⁾			\$2,000				Jun-04		•	
CP-1436 ⁽²⁾		\$92						Sep-04	•	
CP-1427		\$99						Sep-04	•	
CS-1257 ⁽²⁾	\$450				Oct-03					•
CS-1390	\$191				Oct-03				•	
CS-1391	\$483				Oct-03				•	
CS-1393	\$261				Oct-03				•	
CS-1114	2031				Oct-03					•
CS-1394 ⁽³⁾	\$228					Mar-04			•	
CS-1388 ⁽³⁾	\$417					Mar-04			•	
CS-1395	\$420						Jun-04		•	
CS-1332	\$385						Jun-04			•
CS-1438		\$102						Sep-04	•	
CS-1439		\$378						Sep-04	•	
CU-1367	\$119				Oct-03				•	
CU-1372			\$173		Oct-03				•	
CU-1373	\$224				Oct-03				•	
CU-1375	\$345				Oct-03				•	
CU-1235 ⁽¹⁾			\$897			Mar-04			•	
CU-1366 ⁽³⁾		\$279				Mar-04			•	
CU-1370	\$466					Mar-04			•	
CU-1374	\$236					Mar-04			•	
CU-1417		\$170						Sep-04	•	
CU-1419		\$204						Sep-04	•	
CU-1420		\$370						Sep-04	•	
CU-1422		\$319						Sep-04	•	
PP-1411 ⁽²⁾	\$145					Mar-04			•	
PP-1407 ⁽³⁾	\$335					Mar-04			•	
PP-1346		\$419					Jun-04		•	
PP-1059		\$1,000					Jun-04			•
PP-1424		\$361						Sep-04	•	
PP-1425		\$413						Sep-04	•	
PP-1426		\$651						Sep-04	•	
UX-1328	\$554				Oct-03					•
UX-1310	\$220				Oct-03					•
UX-1379	\$511					Mar-04			•	
UX-1414	\$448					Mar-04			•	
UX-1327 ⁽²⁾	\$878					Mar-04				•
UX-1441		\$387						Sep-04	•	
UX-1442		\$480						Sep-04	•	
UX-1443		\$458						Sep-04	•	
UX-1444		\$250						Sep-04	•	
TOTALS	\$11,761	\$7,670	\$3,070	\$0					38	10

⁽¹⁾ Congressional earmark⁽²⁾ Project update to Board—no vote on funding required⁽³⁾ FY04 deferred New Start

Figure III-2. Summary of Proposals Reviewed by SAB in FY 2004 by Thrust Area (Funding in Thousands).

D. Plans for FY 2005

In FY 2005, SERDP will aggressively respond to the increasing challenges of environmental issues impacting training and testing activities as well as the remediation of lands contaminated with UXO. Specifically, in response to the President's FY 2005 budget request and subsequent congressional changes, SERDP issued SONs by thrust area to address the following issues:

Cleanup

- Remediation of emerging contaminants
- Screening level assessment and treatment of explosives and propellant contaminated runoff from training ranges
- Screening levels and toxicity reference values for risk assessments
- Improved understanding of in situ thermal treatment

Compliance

- Characterization and fate of the source term of energetic compounds in aquatic environments
- Environmental fate and transport exposure assessment for energetic materials on ranges
- Identification and characterization of natural sources of perchlorate
- Improved methods and monitoring systems for impulse noise
- Treatment of perchlorate in wastewater

Conservation

- Identification of DoD vectors for non indigenous species transport
- Advanced monitoring strategies for migratory birds on military lands
- Terrestrial biogeochemical cycle models for Fort Benning ecosystems
- Improved remote sensing of threatened and endangered species and habitats

Pollution Prevention

- HAP-free solvents for DoD cleaning applications
- Alternatives for perchlorate in incendiary mixes and pyrotechnic formulations
- Environmentally benign medium caliber gun barrels

UXO

- Site characterization and remediation technologies for UXO-contaminated underwater sites
- Dual mode navigation for portable platforms
- Magnetometer or EMI sensors and processing
- UXO systems integration study

In developing the FY 2005 program, 23 SONs were prepared, with two issued specifically for the SEED program. All SONs were made available to the private sector via a BAA. The Core solicitation resulted in 234 preproposals submitted by nonfederal participants. Of the 162 full proposals that were received from both federal and nonfederal participants in response to the Core Solicitation, 29 were selected for funding. In the SEED solicitation, of the 40 proposals that were received, seven were selected for funding. Figures III-3 and III-4 depict the distribution of Core and SEED proposals selected during the FY 2005 program development process.

CORE PROPOSALS						
Thrust Area	Number of Statements of Need	Number of Proposals Selected	Source			Approximate Value (in millions)
			Federal	Academia	Private	
Cleanup	5	11	3	4	4	\$2.474
Compliance	5	10	5	2	3	\$2.386
Conservation	4	3	2	0	1	\$0.480
Pollution Prevention	3	3	1	1	1	\$1.424
UXO	4	6	2	3	1	\$2.063
Total	21	33	13	10	10	\$8.827

Figure III-3. FY 2006 Core New Start Proposal Distribution by Thrust Area.

SEED PROPOSALS						
Thrust Area	Number of Statements of Need	Number of Proposals Selected	Source			Approximate Value
			Federal	Academia	Private	
Cleanup	0	0	0	0	0	0
Compliance	0	0	0	0	0	0
Conservation	0	0	0	0	0	0
Pollution Prevention	1	0	0	0	0	0
UXO	1	7	0	2	5	\$700,000
Total	2	7	0	2	5	\$700,000

Figure III-4. FY 2006 SEED New Start Proposal Distribution by Thrust Area.

In early FY 2005, SERDP issued SONs by thrust area for projects to be funded in FY 2006 (see Section II for descriptions of FY 2006 SONs). Areas of interest for funding in FY 2006 include:

Cleanup

- Understanding the distribution and impacts of remedial amendments in groundwater and in contaminated sediments
- Measurement of processes impacting the fate and transport of contaminants in sediments
- Containment/treatment of energetic and propellant material releases on testing and training ranges

Compliance

- Characterization of the environmental fate of energetic compounds on ranges
- Environmental transport exposure assessment for energetic materials

Conservation

- Endangered and threatened species habitat fragmentation near DoD installations
- Restoration of longleaf pine for red-cockaded woodpecker habitat
- Scientifically defensible population recovery goals for listed species

Pollution Prevention

- Reduction/elimination of nonhazardous, solid packing waste
- Environmentally benign runway deicing
- Environmentally benign synthesis of energetic compounds and their precursors
- Environmentally benign finishing/coating systems for DoD substrates

UXO

- Innovative signal processing – specifically, exploitation of geophysical data collection at the UXO standardized test sites
- Sensor phenomenology of UXO in underwater environments
- Wide area assessment of sites contaminated with UXO
- Handheld and man-portable platforms supporting geophysical surveys of UXO contaminated sites
- Detection, discrimination, and remediation of UXO

SERDP will continue conducting special studies and gap analyses to identify future opportunities for research and potential opportunities for integration/collaboration to address unmet high-priority research needs. Among the topics that will be addressed in FY 2005 are Environmentally Benign Metal Surface Finishing, Geolocation for UXO Detection, Threatened and Endangered Species, and Molecular Biological Tools for Environmental Remediation.